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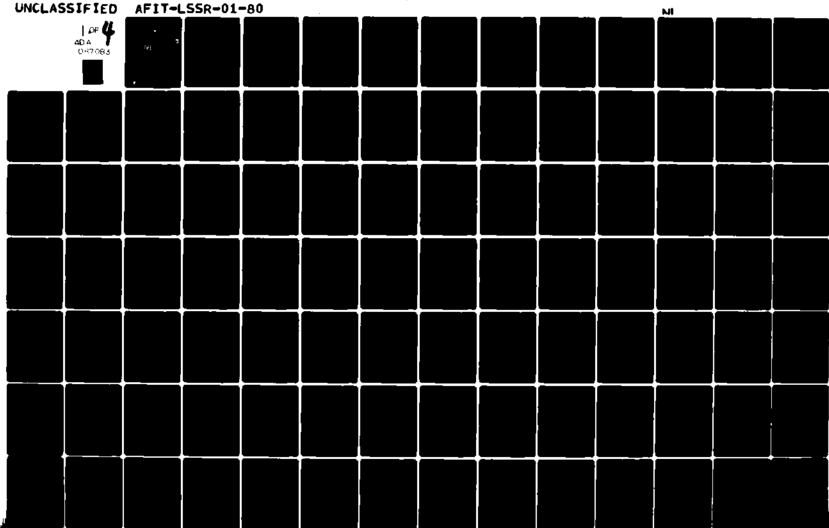

UNITED STATES AIR FORCE

AIR UNIVERSITY

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Wright-Patterson Air Force Base, Ohio

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ENERGY SELF-SUFFICIENCY FOR AIR FORCE LOGISTICS COMMAND (AFLC) BASES: AN INITIAL INVESTIGATION

Charles R. Hatch, GS-12
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LSSR 01-80

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: AFIT-LSSR-01-80	2. GOVT ACCESSION NO.: AD-A087083
3. RECIPIENT'S CATALOG NUMBER: 9	
4. TITLE (and Subtitle): 6 ENERGY SELF-SUFFICIENCY FOR AIR FORCE LOGISTICS COMMAND (AFLC) BASES: AN INITIAL INVESTIGATION.	5. TYPE OF REPORT & PERIOD COVERED: Master's Thesis
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): 10 Charles R. Ray Hatch, GS-12; Robert E. Mansfield, Jr., Captain, USAF	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Graduate Education Division, School of Systems and Logistics, Air Force Institute of Technology, WPAFB OH	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 11
11. CONTROLLING OFFICE NAME AND ADDRESS: Department of Communication and Humanities, AFIT/LSH, WPAFB OH 45433	12. REPORT DATE: Jun[illegible]80
	13. NUMBER OF PAGES: 326
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 12 344	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

APPROVED FOR PUBLIC RELEASE AFR 190-17.

Fredric C. Lynch

FREDRIC C. LYNCH, Major, USAF
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

SELF-SUFFICIENCY, ENERGY FORECASTING, ENERGY POLICY
ENERGY FROM WASTE TECHNOLOGIES
SYSTEMS APPROACH

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Thesis Chairman: Todd I. Stewart, Major, USAF

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012250

To obtain Energy Self-Sufficiency for Air Logistics Centers by the year 2000, has been a stated goal since 1978. The purpose of this thesis was to develop a working definition of Energy Self-Sufficiency; to develop a statistical model for forecasting aggregate energy demand for the Air Logistics Centers; and to research some possible unconventional technologies which may assist in attaining the Energy Self-Sufficiency goal. This research revealed that the goal is rather limited and should be attainable based on the definition provided; aggregate energy demand for the Air Logistics Centers can be predicted by estimating heating and cooling degree days; and waste to energy conversion processes and solar technologies offer some potential for attaining the overall goal.

LSSR 01-80

ENERGY SELF-SUFFICIENCY FOR AIR FORCE LOGISTICS COMMAND (AFLC) BASES: AN INITIAL INVESTIGATION

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degrees of Master of Science in Logistics Management

and Master of Science in Facilities Management

By

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June 1980

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MASTER OF SCIENCE IN FACILITIES MANAGEMENT
(Mr. Charles R. Hatch)

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT
(ACQUISITION LOGISTICS MANAGEMENT MAJOR)
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DATE: 9 June 1980

Todd Stewart
COMMITTEE CHAIRMAN

ACKNOWLEDGEMENTS

We wish to express our sincerest appreciation to those individuals whose advice and assistance helped guide us to the successful completion of this research effort.

Many thanks are due to various members of the faculty, School of Systems and Logistics, for their timely advice. Thanks are specifically due to our thesis chairman, Major Todd I. Stewart, for his continuing guidance, thoroughness, encouragement, and patience; and Lieutenant Colonel Arthur King for his insights.

At Headquarters AFLC we wish to thank Mr. Carl Weilhelm, the AFLC Energy Panel Recorder, for his unending support and advice, and Major George Kastanos of the AFLC Engineering and Services Directorate for generating the request for our thesis effort. Thanks are also due to Colonel James H. Rix, Director of Administration, for his assistance on various matters.

We are indebted to Mr. Curtis Pavy, a fellow student, whose expertise in the finer points of computer programming rescued us on a number of occasions. Our gratitude is due to our typist Phyllis Reynolds for her patience and skill in developing the final thesis effort.

Special thanks are due to our wives, Lori and Jeannine, and our children Shannon, Aaron, and Nathan, for their understanding, patience, and support throughout this year-long undertaking.

Finally, we wish to thank General Merkling for taking time from his busy schedule to submit to an interview.

TABLE OF CONTENTS

Chapter | Page

Chapter		Page

Chapter Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Problem Statement

In recent years it has become apparent the U.S. Air Force is vulnerable to experiencing an adverse impact on its ability to accomplish mission requirements due to heavy reliance on petroleum (95:1) as well as the current world-wide energy shortage. As a result of the 1973 Arab Oil Embargo, continued crude oil price escalations, Organization of Petroleum Exporting Countries (OPEC) production decisions, political turmoil in the Middle East, and labor disputes in United States energy production industries, Air Force officials are beginning to realize that they can exert little other than short-term control over future energy availability for the critical resources (e.g., aircraft, facilities, processes, etc.) under their command.

Due to heavy reliance on purchased fuel, and in many locations on commercially produced energy, Air Force installations are subject to disruptions or termination of activities based on their priority relative to other commercial and community users, as well as on national and local political decisions affecting energy availability. The Department of Defense experienced disruptions as a result of the 1973 oil embargo, the 1976-77 natural gas shortages and the 1977-78 labor problems in the coal fields (96:34). Furthermore, even though current legislation provides for the allocation of energy supplies to meet defense requirements in the event of shortages,[1] there can be some doubt whether under all circumstances the civilian sector would long stand for the diversion of energy supplies (56:46).

Although U.S. energy problems are multifaceted and complex, these problems may be reduced or resolved as the nation becomes more reliant upon its own energy resources and as alternative energy sources are developed. Likewise, a move toward energy self-sufficiency for military installations may provide greater energy security for defense-related uses. This notion was expressed by General Bryce Poe II, Commander of the Air Force Logistics Command (AFLC), at an Air Force Association symposium at Los Angeles, California in October 1978. The theme of the symposium was "Toward a New World Strategy" and General Poe said that the energy shortage was "the single most influential factor in our new strategy [77]." He indicated that AFLC is "one of the most energy-vulnerable of the Air Force commands [77]," and that "I have told my command engineers that by the year 2000 I want AFLC independent of outside oil, coal or purchased electricity [77]."

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[1]This legislation is discussed further in Chapter IV.

As a result of General Poe's statements the Air Force Logistics Command has stated as its highest priority objective in the AFLC Energy Master Plan that "the command will achieve self-sufficiency in industrial energy by the year 2000 [2:14]." While this is a stated goal, AFLC has not fully developed an operational definition of energy self-sufficiency (ESS) from which to begin progressing toward the goal. Before this goal can be adequately pursued some definition of the meaning of energy self-sufficiency for AFLC industrial facilities and processes must be developed. The purpose of the research presented in this thesis was to determine a definition of AFLC energy self-sufficiency for industrial facilities and processes, develop an energy forecasting model that could be useful in achieving this goal, and present some energy technologies that may possibly be useful to make AFLC energy self-sufficient.

Systems Approach to Energy Self-sufficiency

There are numerous factors and interacting elements which will affect the attainment of energy self-sufficiency by AFLC Air Logistics Centers (ALCs). Knowledge, understanding, and specification of these factors and elements are essential before the ESS strategy can be realistically pursued and appraised. A systems approach to the analysis of the concept of energy self-sufficiency is an especially valuable method. The concepts and methodology of systems theory (sometimes called systems philosophy) help to unify and relate the complexities of problems and physical and conceptual arrangements as well as to specify relationships and outcomes of interactions.

A system is defined as "an assembly or set of related elements [107:2]," or "many components and objects united in the pursuit of some common goal [19:46]," or "the principle of functional combination of resources to produce intended results or effects [37:1]." In other words, a system is a related collection of elements relevant to some function or goal. Additionally, every system can be thought of as part of another system until some lowest level of the elementary subsystem is reached (107:66).

Systems must be viewed as a whole rather than simply an aggregation of subsystems or components. This is opposed to the concept and analytical technique of reductionism which "is based on the idea that complicated phenomena or higher levels must ultimately be reduced to elementary phenomena [11:116]." Reductionism serves useful purposes in many investigations; e.g., biological, but

> Such practice, while contributing much noteworthy detailed knowledge of isolated events, leaves out of consideration larger interconnections which may be decisive for the understanding of the phenomena [58:6],

and "gives us no information about the coordination of parts and processes [11:152]." It is necessary to determine how each subsystem functions, but each subsystem must support the entire system and the overall system's goals. The entire or Whole System is "comprised of all the systems deemed to affect or to be affected by the problem at hand, regardless of the formal organization to which they belong [107:15]." All other systems are then considered to be part of the environment. Since the system of interest lies within an environment, it is also affected by it. Likewise, the environment is composed of subsystems.

Because of the nearly infinite number of components that could be considered to affect a problem or other complex arrangement (such as ESS), that which is analyzed as a system must function under some restriction. The restriction of a system stipulates the internally (Whole System) and the externally (environmental) imposed guidelines that bound the problem (70:59). Without some restriction or bounding of the system of interest, analysis would be unmanageable. Additionally, decisions must be made as to which variables in the analysis will be managed while others are held fixed in order to identify influences and responses among and between variables (87).

Figure 1 illustrates, in a macro view, energy self-sufficiency (the system of interest) in its environment with major environmental subsystems. The figure shows that environmental factors not only interact and influence the Whole System of interest but also one another. Divisions of the environmental factors (represented by the dashed

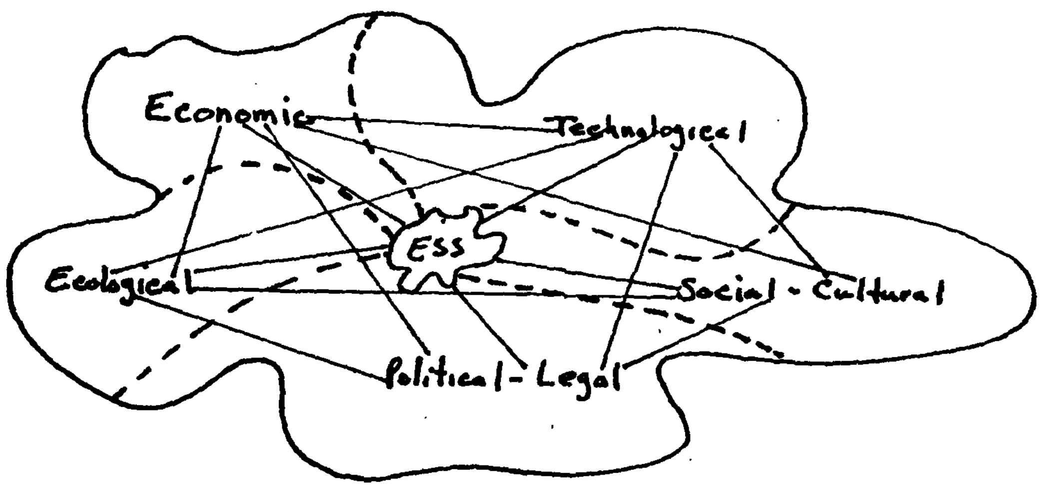

Fig. 1. Macro View of ESS System in its Environment (87; 47:85-111)

lines) are not rigid and their relative importance to the system under consideration determines the "size" (amount) of their influence. Some of the subsystems of the environmental system may themselves be part of the Whole System, in this case ESS. For example, economic considerations such as cost and resource availability, and technological factors such as energy production and distribution systems could, depending on how the Whole System is founded, be part of it.

The Whole System, once bounded, contains elements and components which interact and influence one another, and affect attainment of the system's goal(s). Figure 2 illustrates this. The variables are offered as examples of but a few of the possible ones in the ESS system. For example, isolating the component "design and construction" of new energy facilities reveals that this component has over 350 elements that can affect the system. This finding was made by reviewing the requirements for project books of military construction programs as outlined in Air Force Regulation 89-1 Design and Construction Management (105). Each of these components could be treated as a system itself with a number of interacting elements.

Another example is a power system. Energy self-sufficiency implies some sort of power or energy system. Transmission system(s), distribution system(s), as well as the type of load characteristics, i.e., commercial,

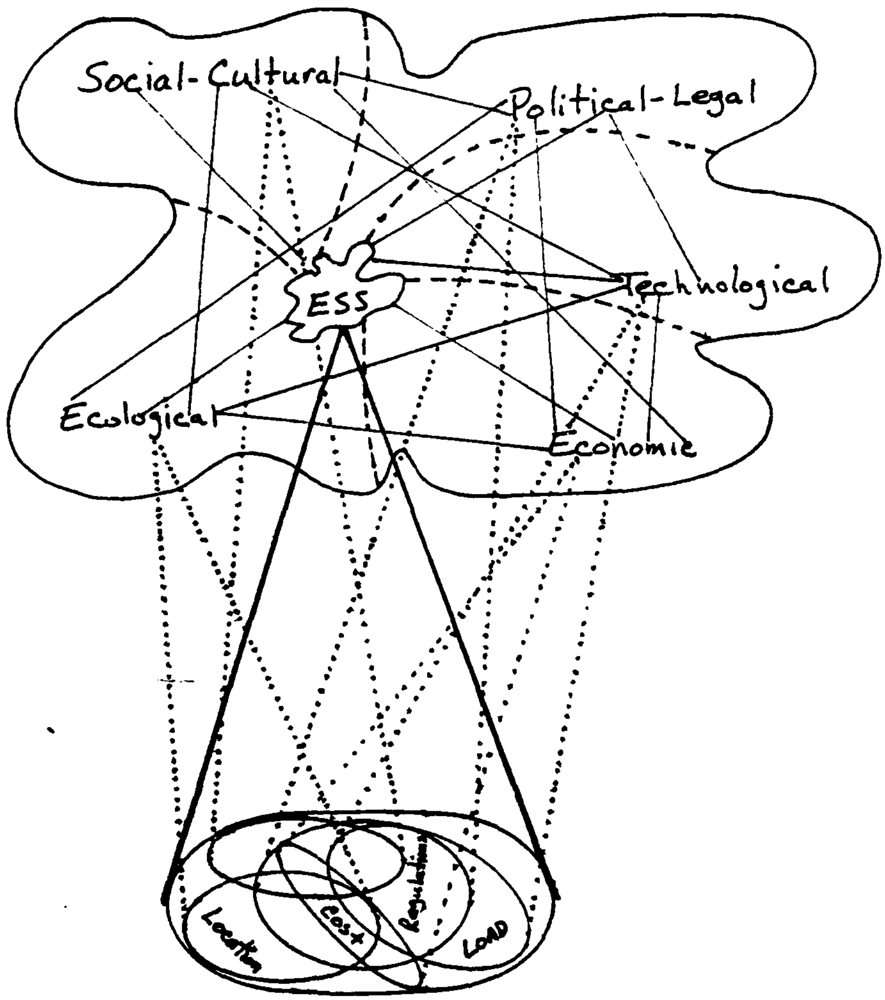

Fig. 2. ESS System Bounded (variables included for illustrative purposes)

residential, industrial, or other (92:17-20), would influence the energy self-sufficiency system. If the power system were to be an electrical system, in its simplest form it would contain an energy source, a prime mover, generator, load, and control system (32:4-6). Figure 3 illustrates this simple electrical power system. The energy source may be coal, gas, oil, etc.; the prime mover converts the energy source into a useable form, e.g., heat or shaft rotation; the generator supplies the electric power; the load may be lights, motors, etc.; and the control system keeps the system functioning as intended (32:4-6). There are, of course, a number of factors that could affect each of the components which in turn affect the Whole System.

Before energy self-sufficiency can be realistically attained, some systematic analysis of the requirements of the system must be done. Such an analysis can reveal methods and economies, and avoid or lessen mistakes. A principle requirement for achieving energy self-sufficiency (in addition to a definition of ESS) is a determination of some level of energy consumption. Generally, such planning begins with "a forecast of anticipated load requirements [92:18]." Without some notion of the quantities of energy needed, self-sufficiency requirements cannot be determined.

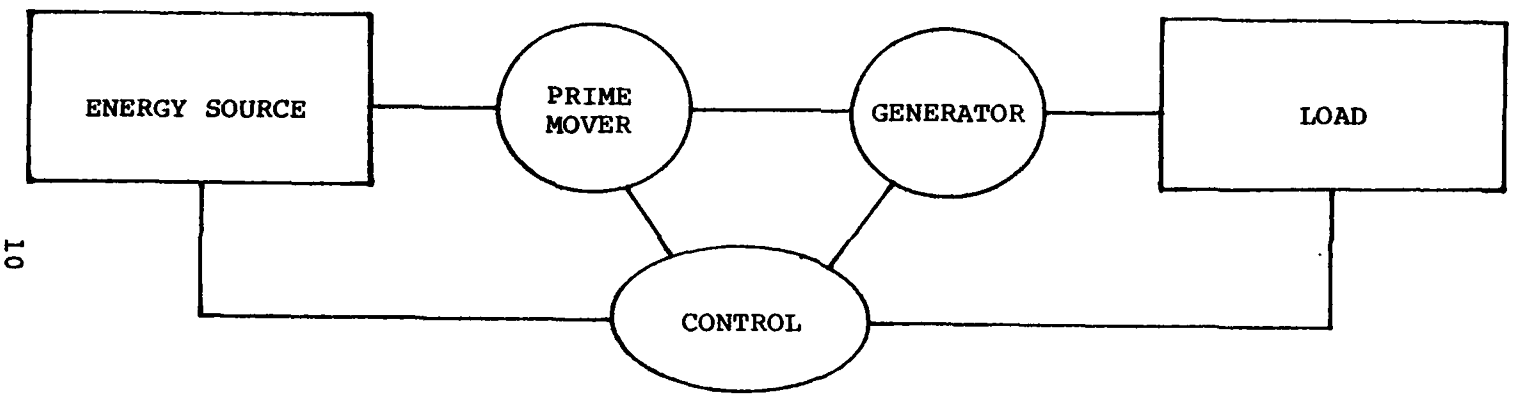

Fig. 3. Simple Electrical Power System (32:4)

Research Objectives

The objectives of this research were to ascertain a definition of energy self-sufficiency for AFLC Air Logistics Centers; to develop a statistical model which encompasses the major factors of ALC energy consumption; to use the model to forecast levels of energy consumption which could be considered in planning for ALC energy self-sufficiency; and to describe some possible technologies that could be used to achieve ESS for AFLC Air Logistics Centers.

Scope of the Research

The research was concerned with aggregate Air Logistics Center energy consumption for facilities and industrial processes. Aviation, vehicle and other energy uses were not included. Aggregate energy consumption was used in order to get some notion of Whole System's energy requirements. Some attempt was made to relate the model to individual ALCs for the purpose of testing the sensitivity and validity of the forecast model. The discussion of possible energy technologies does not consider in detail the many factors that may influence their use. They are presented as possible means for achieving energy self-sufficiency. Also, no in-depth analysis is presented as far as their specific application to any one Air Logistics Center.

Because any energy self-sufficiency strategy will require some consideration of the availability and sources of energy, a review of principal U.S. energy sources is given. Likewise, since political and management philosophy factors will affect ESS, a summary of energy policy and political questions is presented.

Definition of Terms and Concepts

Technical terms, acronyms, and concepts used throughout this paper are found in Appendix A. Acronyms are defined in the initial appearance, and are used interchangeably with their entire definition throughout the text as seems appropriate.

Structure of the Report

The first four chapters form the background of the current energy situation. Chapter V deals with the definition of AFLC energy self-sufficiency. Chapter VI presents the statistical forecast model. The methodology used in both chapters V and VI is given in the respective chapters. Chapter VII describes various energy technologies AFLC may consider for attaining ESS for their facilities and industrial processes. Chapter VIII gives recommendations and conclusions based on the research, and presents topics for further study.

Chapter Summary

This chapter gives the problem statement and objectives of the research. A definition for energy self-sufficiency will be presented and a forecasting model for aggregate Air Logistics Center energy consumption will also be presented. A systems approach is an appropriate method to study and plan for ESS in AFLC. An operational definition and a forecast of energy consumption are but a beginning of such an analysis. The next three chapters present a background on energy.

CHAPTER II

OVERVIEW OF ENERGY

Introduction

After reviewing the various components which affect the energy self-sufficiency system it became apparent that development of an ESS strategy would depend largely upon the primary energy options that are available at the present time. It was also necessary to look at their potential in future years. This chapter provides a historical look at the nation's energy evolution. Also, the major sources of domestic energy are addressed in a literature review. Separate sections are provided for petroleum, nuclear, coal, natural gas and hydroelectric. The energy sources are reviewed with respect to their current and potential contribution and advantages and disadvantages.

The reader should be aware and appreciate the complex interrelatedness between each of these energy resources. The authors have attempted to discuss various environmental, economical, social-cultural, political-legal and technological considerations of the energy resources; however, it was not the purpose of this thesis to determine the complicated impact that one energy resource may have on another. Also no attempt was made to show "cause and effect" relationships to the energy self-sufficiency systems model.

The following section provides a general background of energy usage. Particular emphasis has been given to the energy usage evolution in the United States.

Evolution of Energy Usage

Energy has played a principle role in the evolution of human civilization. Through the centuries humankind's social, economic, and political development can be traced in parallel with our sources and uses of energy (30:2). The discovery and use of fire offered a new and powerful source of energy. It gave us an additional source of heat, improved tool making and food preparation, offered protection from predators and allowed for expanded habitation into the cooler regions of the world (38:47-48). The use of animal energy, through the domestication of dogs, cattle, and horses greatly increased our productive capacity, particularly that of food. Animal-derived energy began to free humankind from directing all his efforts toward basic survival. The development of devices and machines using the energy derived from fire, wind, and water finally freed humankind from a subsistence existence. The discovery and widespread use of fossil fuels initiated the modern age of energy use. It was energy obtained chiefly from coal that powered the Industrial Revolution (43:11). It is with the Industrial Revolution that the dependence on fossil fuels as a major source of energy began (74:5). Wood and water were displaced by coal as the primary energy source to power the mills and engines. Later, coal would be displaced by oil and gas as major sources of energy.

Energy Usage in the United States

The substitution of fossil fuels for other forms of energy has been in effect total. Oil and gas supplied nearly three-quarters of the energy used in the United States in 1977[2] (30:2). Furthermore, plentiful, cheap energy became a way of life in the United States--a given. The prosperity of the United States following World War II was built on this given. Oil and gas have been the primary sources of energy during the post-World War II era. This occurred because of the low prices compared to other energy sources and the fact that the U.S. was able to produce more of the oil and gas than it consumed (2:10). Little consideration was given to the finite nature of our primary energy sources. It was thought that nuclear energy generation would be developed long before our fossil fuels

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[2] In 1850 two-thirds of the work in the USA was done by animal power; with 10 percent done by fuel combustion. By 1950 nearly 90 percent of the work was done by fuel combustion and less than 2 percent by human beings and animals (81:214). In 1977 oil constituted 48 percent of the consumption while gas accounted for 26 percent. Coal, nuclear and other energy sources accounted for 19 percent, 4 percent and 3 percent respectively (94:4).

ran out. However, that has not happened. Consumption and reliance on finite fossil fuel sources has increased, and our ability to produce domestically what we need has decreased. The Arab Oil Embargo of 1973 quickly brought to our attention that we faced a national, even world-wide "energy crisis."

Our national energy problem had been developing for some time. United States petroleum reserves began declining in the 1950s and 1960s and proven world reserves began increasing. U.S. natural gas reserves peaked in 1967 and production peaked in 1973. Domestic petroleum production reached its peak in 1970 (30:7-8) while demand was reaching all-time highs. The excess demand over domestic supply was made up by plentiful, cheap[3] foreign oil, primarily from the Middle East. Part of this increased consumption of oil and gas was a result of domestic policies.

Beginning in the late 1960s and early 1970s, our nation became seriously concerned with the quality of our natural environment. Americans found that various forms of environmental pollution contributed to disease, higher mortality rates, deterioration of buildings and works of art, and generally degraded the quality of our lives. The

[3]The real price of gasoline and fuel oils actually decreased by 25 percent from 1951-1973. Expenditure on energy remained between 7.1 percent and 7.6 percent of the average consumer budget, despite a 50 percent increase in per capita energy usage (74:27).

Environmental Protection Agency was established in 1970 and adopted many new laws and regulations to reduce pollution, and preserve and protect environmental quality. Unfortunately, some of these environmental protection measures had the effect of increasing oil and natural gas consumption.

The Clean Air Act of 1970 is one piece of legislation that contributed to actions being taken which increased oil and natural gas consumption. The Act requires that emissions from power plants and automobiles be reduced to meet certain standards of minimum air quality. Power plants and automobiles are the major source of air pollution; with the automobile contributing 60 percent of the air pollution (74:14).

The Emission Standards Act for automobiles had the effect of increasing automobile direct petroleum usage by 10 percent in 1973 and an additional 9 percent by 1976. This increase can be attributed to lower engine compression ratios and the increased quantities of crude oil needed to refine unleaded gasoline as compared to leaded (74:14-15).

The major source of fuel for power plants supplying energy for the production of electricity and industrial processes prior to the late 1960s had long been coal. Up to 38 percent of the nation's energy consumption had come from coal. However, coal when burned creates sulfur dioxide, a major pollutant. Because of the expense and difficulty in removing sulphur dioxide from the combustion process of coal, industries that could, shifted away from coal as a primary source of fuel to oil and natural gas.[4] Others were forced to make large investments in pollution control systems. By 1972 coal supplied only 17 percent of the nation's energy consumption. Furthermore, the use of coal as a source of energy for electrical power generating declined from a high of 70 percent to 54 percent (74:15-17).

Estimates of oil and gas reserves for the United States at current rates of consumption are estimated at 15 to 18 years for known crude oil and 20 to 25 years of natural gas reserves (73:2). Because of domestic controls on the price of crude oil and natural gas, not only has consumption outstripped production, but discovery of new reserves has not been keeping pace with annual increases in consumption.

Summary

The U.S. reliance on large quantities of cheap, plentiful fuel, some of the national policies on environmental production, oil and natural gas price controls, and the inefficient use of energy, led Americans to a point

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[4]Natural gas is most efficient when put to residential and small commercial uses. The use of natural gas to fire large boilers to produce electricity results in a net energy loss. It takes three BTUs of natural gas to produce one BTU of electricity (74 :19).

where we can no longer produce all our national energy needs. We have come to rely on foreign sources for nearly 40 percent of our energy requirements (30:16). The Arab Oil Embargo of 1973 did not cause our energy problem, it simply brought it into our national consciousness.

The next section is concerned with the status of major domestic energy sources, some of which must be relied upon more heavily if the country is to regain some degree of energy self-sufficiency. Petroleum is the first resource to be discussed.

Status of Conventional Energy Sources

Petroleum

The U.S. oil industry had its origins in the middle of the nineteenth century. This occurred when kerosene began to replace expensive whale oil as a source of lighting. Most kerosene was made from coal; however, some was extracted from crude oil. At this time crude oil could only be obtained from areas where it naturally seeped to the surface or from brine water wells. Since kerosene was priced at $42 a barrel, an opportunity existed for anyone who could find a cheap and easily available supply of crude oil (88:17). A company was formed by a group of New Haven investors to drill for oil in the vicinity of brine wells in Pennsylvania. Edwin Drake was hired to head the venture.

On August 27, 1859 Drake struck oil near Titusville and the modern oil industry was born (88:17).

> For more than a century thereafter, the production of crude oil in the United States steadily increased. In 1909, the fiftieth year of the industry, U.S. production reached 500,000 barrels a day, more than the rest of the world combined [88:17].

Except for several years after World War I, the U.S. was one of the world's leading petroleum exporters.

As time went on, American companies produced, refined and distributed oil to an ever wider and more diverse market. Inexpensive oil slowly shoved aside coal, and became the basic source of power for an industrial civilization. Oil was often considered a premium fuel because of its ease of extraction and refining into various products. In addition, it is a much cleaner source than coal.

In 1948 imports--mostly Venezuelan crude--exceeded American oil exports, which meant that the United States had become a net importer of oil.

> Nevertheless, the United States continued to produce half of the world's oil in the early 1950's. Furthermore, it had sufficient unused capacity to produce for export markets in an emergency, as happened during the Suez Crisis of 1956 [88:17].

Eventually American oil could not compete with the low-cost crude that was beginning to flow in large quantities from the Middle East. For the reason of national security and also to protect the politically powerful domestic oil producers, restrictions were placed on imports by the U.S.

Government. Since it was protected, domestic oil production continued to climb in the late 1950s and through the 1960s.

> The historic turning point came in 1970, when U.S. spare capacity vanished and U.S. production reached what proved to be its peak--an average of 11.3 million barrels a day. From then on, the level of oil production began to decline [88:18].

Since demand continued to increase, imported oil began to constitute a larger and larger share of the U.S. market. Eventually the oil import barriers were lowered. The Nixon administration completely abandoned import quotas in 1973 since sporadic shortages had begun to develop around the country (88:18).

Before discussing the U.S. consumption and production of petroleum, a brief look at world production is provided. M. King Hubbert believes that based on "an orderly undisturbed evolution of the petroleum industry," world oil production would peak at a rate of 37 billion barrels of oil/year during the mid 1990s (94:26). It is recognized that production depends on economic and technical feasibility of extracting oil, methods used to estimate reserves, and the degree of certainty assigned to the estimates.

Theoretical world oil exhaustion dates range from a low of 2003 to a high of 2070. Using the historical growth rate of 7 percent, exhaustion of supplies would occur between 2003 and 2007. At a more conservative

2.5 percent annual growth rate, recoverable resources would be exhausted between 2017 and 2025. The most optimistic case of no increase in consumption would provide for exhaustion by 2070 (94:26).

The annual consumption and production of petroleum in the U.S. is shown in Table 1 (31:116).[5] The way in which petroleum is utilized in the U.S. is depicted in Table 2 (31:118).

Recently the Oil and Gas Journal predicted that the demand for oil products would drop this year which would be the second year in a row.

> Conservation, reduced economic activity and higher prices will account for a 2.7-percent decline from 18.5 million barrels per day in 1979, the Tulsa-based magazine said [28:10].

The availability of petroleum as a domestic energy resource and its production depend upon a number of parameters, some of which are related to the geology of the earth and to the techniques for oil production, while many others are dependent upon economics, governmental regulations, material and equipment supply, and similar factors. A prediction of future oil supplies will be found in a composite assessment of several questions:

> (a) How much oil is there to be found? (b) How effectively and rapidly can new oil deposits be located? (c) How much of the oil that has been found or will be found will be recovered? and (d) How fast can known oil be produced [31:119]?

---

[5]By 1977 petroleum consumption had grown to 6158 millions of barrels (94:3).

TABLE 1

ANNUAL CONSUMPTION AND PRODUCTION OF PETROLEUM IN THE U.S. [31:116]

Year	Consumption (Millions of Barrels)*	Domestic Production (Millions of Barrels)	Imports as Percent of Consumption
1920	434	443	2%
1930	862	898	4%
1940	1,285	1,353	5%
1950	2,375	1,974	17%
1960	3,611	2,575	29%
1970	5,365	3,517	34%
1974	5,900	3,500	40%
1980 (Projected)	7,200	4,000	44%

*One barrel of petroleum equals about 6.0×10^6 Btu or 6.3×10^9 joules.

TABLE 2

USES FOR PETROLEUM IN THE U.S. [31:118]

Type of Use	Consumption (10^{12} Btu)*	Percent of Total
Residential and commercial	6,545	21.6%
Industrial	5,091	16.6%
Transportation	16,267	53.3%
Electricity generation	2,417	7.9%
Other	172	0.7%
TOTAL	30,492	100.0%

*One barrel of oil equals about 6×10^6 Btu.

Answers to each of the questions can at best be an estimate and uncertainties in the estimates arise from both nonphysical and physical factors.

Samuel M. Dix, in his book Energy: A Critical Decision for the United States Economy, noted some facts that cannot be altered. Among those he presented are two which are basic but need to be remembered (30:11):

> (1) The supplies of petroleum and other fossil fuels are finite. We know their origin and where they are likely to be found. The geological time unit for their formation is one hundred million years and several are required. Petroleum is a non-replaceable resource.
>
> (2) The mathematics of withdrawal from a fixed resource in uniform exponential growth is compound interest operating in reverse. Each time the rate of withdrawal doubles, the amount of the total withdrawal from the beginning also doubles. It took

> one hundred years to withdraw the first one hundred billion barrels from the U.S. resource on a growth curve of approximately 4% per year. The next hundred billion barrels will be withdrawn in eighteen years at this rate. The following doubling will require two hundred billion barrels, in only eighteen more years.

Richard Dorf, in his book Energy, Resources and Policy, estimates that the U.S. total resource of petroleum is approximately 200 billion barrels. By 1975, 100 billion had already been extracted and proven reserves amounted to only 34 billion barrels. This left 66 billion remaining to be discovered. Naturally, the actual recoverable petroleum in the U.S. may differ from the estimate.

> The U.S. Geological Survey and the National Academy of Sciences differ on the estimate of the ultimate resource of crude oil. The Academy estimate is 213 billion barrels as a total resource, while the Survey estimates an ultimate resource of less than 200 billion barrels [31:212].

The percentage of oil recovered from a deposit is usually only 30 percent of the total. If the other 70 percent could be economically recovered, then the oil fortune of the U.S. would increase substantially. It is thought that secondary and tertiary recovery could double the proportion of resource recovered from known deposits.

> Secondary recovery relates to oil obtained by the augmentation of resevoir energy, often by the injection of air, gas, or water. Tertiary recovery means the use of heat and methods other than fluid injection to augment oil recovery, and takes place after secondary recovery [31:123].

The use of fluid injection is being widely applied and was responsible for about 35 percent of total oil production in 1974.

It has been estimated that during the 1980s, at least 40 percent of the known oil in place should be recoverable as compared to 30 percent normally. If this occurs, it will increase recoverable reserves by large quantities. Even this ratio could be increased if tertiary recovery can be made more economic and energy efficient. As the U.S. oil industry is freed from price regulation, new and improved secondary and tertiary methods may evolve (31:123).

As an alternative to increasing imports from OPEC countries, the U.S. has been looking at greater exploration and exploitation of offshore oil resources. Oil and gas has been actively extracted from the continental shelf for more than twenty-five years, mostly in the Gulf of Mexico and off the coast of California. Recent exploration has centered on the coast of Alaska and off the coast of the Eastern U.S.

While oil companies hoped to expand oil production from the ocean floor over the next decade, incidents such as the blowout in the Santa Barbara channel in California have focused attention on the adverse environmental effects which are possible by this technology.

> Nevertheless, exploration is proceeding. The locations in the U.S. where the promise is greatest include Georges Bank on the continental shelf off Cape Cod, the

> Baltimore Canyon Trough across the shelf of Delaware, the Southeast Georgia Embayment, and Blake Plateau off the southern coast of the Atlantic seaboard [31:129].

Additionally, there is interest in more exploration off the California coast.

> Of the 100 billion barrels of estimated U.S. offshore resources, only about 40 billion barrels can be economically exploited within the framework of today's oil prices and technology. However, as the technology of deep-sea drilling and production improves, we might expect to exploit a greater percentage of this resource [31:129].

Although the future of this energy resource holds promise for additional discoveries, petroleum is a finite resource which is best suited for premium uses. Many other energy resources are necessary to provide for a growing economy.

<u>Summary</u>

This section has provided a brief background of the development of the use of petroleum. World reserves and depletion forecasts were presented and a discussion of U.S. consumption and production of petroleum were provided. The future direction of exploration and the promise that it provides was summarized.

Petroleum is a premium energy resource with a finite lifetime remaining. Although many opinions may exist as to the life of this resource, it is clear that the future use of petroleum is relatively short.

The next section of this chapter is concerned with nuclear energy. Nuclear has held out the promise of providing a significant contribution to the energy dilemma and for filling the void left by petroleum.

Nuclear

Probably the main cause of complacency in the past with regard to future energy supplies was undoubtedly the emergence of nuclear energy. People felt that it had arrived just in time and did not bother to inquire precisely what it was that had arrived (20:134). Nuclear was new, it was astonishing, it was considered progress and promises were freely given that it would be cheap. Eventually a new source of energy would be needed and the public asked, why not have it at once (20:134)? The following statement was made about thirteen years ago and seemed highly unorthodox (20:135):

> The religion of economics promotes an idolatry of rapid change, unaffected by the elementary truism that a change which is not an unquestionable improvement is a doubtful blessing. The burden of proof is placed on those who take the "ecological viewpoint": unless they can produce evidence of marked injury to man, the change will proceed. Common sense, on the contrary, would suggest that the burden of proof should lie on the man who wants to introduce a change; he has to demonstrate that there cannot be any damaging consequences. But this would take too much time, and would therefore be uneconomic. Ecology, indeed, ought to be compulsory subject for all economists, whether professionals or laymen, as this might serve to restore at least a modicum of balance. For ecology holds "that an environment setting developed over millions of years must be considered to have some merit. Anything so complicated as a planet, inhabited by more than a

million and a half species of plants and animals, all of them living together in a more or less balanced equilibrium in which they continuously use and re-use the same molecules of the soil and air, cannot be improved by aimless and uninformed tinkering. All changes in a complex mechanism involve some risk and should be undertaken only after careful study of all the facts available. Changes should be made on a small scale first so as to provide a test before they are widely applied. When information is incomplete, changes should stay close to the natural processes which have in their favour the indisputable evidence of having supported life for a very long time.

Of all the changes introduced by mankind into his environment, large scale nuclear fission is probably the most dangerous and profound. As a result, ionizing radiation has become a serious agent of pollution to the environment and a possible threat to man's survival on earth. The attention of the layman has been captured by the atom bomb, although there is at least a chance that it may never be used again. The danger to humanity created by peaceful uses of atomic energy may be much greater (20:135). In the past the decision to build conventional power stations, based on coal or oil, or nuclear stations, was decided on economic grounds with a small element of regard for the social consequences that might arise from a rapid curtailment of the coal industry (20:135). The fact that nuclear fission represents an incredible, incomparable and unique hazard for human life, was seldom considered in the calculations to exploit nuclear power. The insurance companies, whose business it is to judge hazards, were reluctant to insure nuclear power stations anywhere in the world for third party risk. The result was that special legislation had to be passed whereby the state had to accept big liabilities (20:136). Insured or not, the hazard remains.

It is not as if there were a lack of warning about nuclear problems. The effects of alpha, beta, and gamma rays are well known. Since November 8, 1895, when Wilhelm C. Rontgen identified X-rays, overt injury has been noted by ionizing radiation. In the same month that Rontgen announced the discovery of X-rays, E. H. Grubbe, working in Chicago with Crookes tubes to fluoresce chemicals, saw the back of his hand reddening, swelling, and becoming very sensitive. The skin cracked, ulcerated and scarred (22:432).

Public fear of ionizing radiation, which many cannot dissociate from the demolitions of Hiroshima and Nagasaki, has made control not only acceptable but demanded as a condition for the presence of radiation sources in the community (22:433).

It is too soon after the nuclear power plant accident near Harrisburg, Pennsylvania to say confidently whether commercial use of nuclear energy has a future in the United States. As industry and government continue to analyze the March 1979 incident, some flatly predict nuclear energy has no future while others claim that the industry will emerge even stronger (115:35).

There is a strong antinuclear movement demanding that existing nuclear plants be closed down and that construction be halted on any new ones. Industry experts have noted that nuclear power provides 12.5 percent of all electricity generated in the country and without it, the United States would have to turn to coal on an even greater scale to meet its power demands (1:32).

Some experts believe that despite the scare at Three Mile Island, the known risks of burning coal are greater than the risk of nuclear power.

> The United States must retain the nuclear option, but it should make some immediate changes in licensing and regulation and promote a crash program to solve the long-term waste-disposal problem [1:32].

The accident will probably result in a much tighter government regulation of the industry, with public officials making more of the decisions about the manufacture, operation, and safety of nuclear power stations. Any future development of commercial nuclear power will probably proceed more slowly than it did before. States may be required to develop evacuation plans and rehearse them (115:35).

Past projections of the number of nuclear power plants to be in operation by the year 2000 have ranged up to 500 and producing about a fourth of the nation's generating power. The actual number will now probably be short of that. About 80 additional plants now under construction or in the licensing process are expected to become operational around 1987. Utilities have notified the Energy Department of their intention to proceed with those plants (115:35).

The accident has not affected public attitudes toward nuclear power as much as some critics might have expected. Although the reason is unclear, it may stem from a general awareness of the length of time (twenty-two years) nuclear power stations have been in commercial operation without a serious accident (9:35). In a poll conducted prior to President Carter's July 15, 1979 energy message, Louis Harris and Associates asked Americans: "In general, do you favor or oppose the building of more nuclear power plants in the United States [115:35]?" Fifty-two percent were in favor of more atomic generating stations, 42 percent opposed and 6 percent were unsure. In 1978 the same type of poll revealed that 57 percent said they supported more nuclear power plant construction, 31 percent were against and 12 percent were unsure (115:35).

William Ramsey, a nuclear physicist, is afraid that it is possible for us to lose the nuclear option in the United States. He notes:

> The recent accident does not necessarily mean the risks of harnessing the atom for peaceful use outweigh the benefits . . . this is a good time for the nation to review the whole reactor program [115:35].

According to Ramsey, the future of nuclear power will ultimately be determined by the continuing rise in the price of foreign oil and the availability of other energy sources such as coal. He believes that nuclear power may look very attractive again (115:35).

A number of problems had already occurred in developing nuclear generating plants prior to the Three Mile Island incident. These were primarily construction cost overruns, thermal pollution, and spent-fuel storage problems. Ecological considerations for thermal pollution, spent-fuel storage and greater safety requirements have largely contributed to the problem of cost overruns.

Nuclear fueled electrical generating stations as presently designed must dissipate from 25 to 30 percent more heat than fossil-fueled plants of equal generating capacity. This thermal pollution must be dissipated in rivers, streams or the ocean. The complex of physical and biochemical factors which support all aquatic life and the waterfowl dependent on it is just beginning to be known. The aquatic life now evolved has some tolerance for the natural cycle variations of temperature, tides and flows. The range of tolerance is not great for any species and very narrow for some. An example would be dissolved oxygen and its effect on fish (22:129). Artificial changes caused by nuclear thermal waste may be only moderately disturbing or drastically disrupting. Changes can be immediately obvious or slow in changing an existing balance.

> The variety of conditions which can upset the balance for one species is multiplied by the responses set off in other species dependent on the first by

predation or symbiosis or on environmental modifications maintained by the first species [22:129].

Alternatives to conventional cooling by river water are expensive and often cause other ecological problems. Some examples are the following (22:130):

1. Air-cooled condensers--with the disadvantages which at present result in massive structures, high evaporative losses, localized fogs, and some radioactive releases.

2. Artificial cooling ponds of immense size, with special variances on what water quality and aquatic environment must be maintained.

3. Continued work to develop nuclear-reactor heat-utilization systems with resultant smaller amounts of heat to be dissipated.

4. Heat recovery systems as by soil heating, for large hot houses for year-round horticulture.

5. Controlled discharges to benefit an existing or acceptable ecosystem by thermal enrichment.

The nuclear-power industry is faced with the problem of processing and storing of nuclear wastes. Spent-fuel and surrounding fission products are radioactive and remain so for hundreds of years. Radioactive wastes are created when spent nuclear fuel is removed from commercial or military reactors. The material is processed using nitric acid; however, a brew of liquid wastes containing strontium-90, cesium-137 and other toxic and long-lived substances are formed (31:232). Strontium and cesium in this liquid form take 600 years to decay to harmless levels. Plutonium is deemed hazardous for 250,000 years. All of these wastes must be stored (31:232).

The U.S. Government has already placed into storage over 81 million gallons of waste and about 8 million gallons are added annually from military sources alone. Storage of long-term radioactive waste to protect our environment is a major challenge to the industry. "Any storage approach must meet the following criteria [31:233]:"

1. The wastes must be isolated for 250,000 years;

2. The storage sites must be proof against sabotage or theft.

Stobough and Yergin in their book Energy Future, believe that because of the problems associated with nuclear waste there is no possibility for massive contributions from nuclear power for at least the rest of the century. They believe that unless government and industry leaders start now to work with the nuclear critics, many plants will run out of spent-fuel storage within four years (33:135).

The Ford Foundation sponsored an eighteen-month study on resources for the future and was chaired by Hans Landsberg, Director of the Center for Energy Policy. The study group noted in one of its recommendations that nuclear power should not be excluded as an energy option either in the United States or abroad, either in the short or long run. While noting that the environmental effects of energy use will remain "serious and hard to manage," the authors are "cautiously optimistic" about the environmental effects of future energy production:

> . . . given careful and flexible management, energy can be produced and consumed in the United States at levels we think likely over the next 20 years, without undue harm to human health, natural systems or aesthetic values in general [57:1453].

The National Academy of Science released a 783-page report entitled "Energy Transition 1985-2010." The report noted that coal and nuclear power are the only large-scale alternatives to oil and gas for the next 20 years. The group pointed out that the environmental and health effects of routine operation of nuclear reactors are substantially less than those of coal per unit of electric power produced (26:10). However, the group did note that if one takes the most optimistic view of the health effects of coal-derived air pollution and the most pessimistic view of the risk of nuclear accidents, coal might have a small advantage in such a comparison (26:10).

Newsweek magazine recommends that spent fuel now stored at reactor sites should be moved to federal dump sites perhaps in Nevada or Washington state.

> With tough standards governing their transport and entombment, they can be made safe for the next few decades--and the relatively small amount of added waste that will be produced by the end of the century will not jeopardize national safety [1:32].

The federal government should launch a program to find out if there is a more satisfactory way to dispose of the long-lived, highly toxic waste.

> If no solution is feasible within five years, the U.S. may well have to abandon plans to build any more nuclear reactors. No solution to the nuclear waste problem will ever satisfy everyone [1:32].

Summary

While nuclear power provides much promise as an alternative to the use of petroleum, it has a number of drawbacks which must be resolved if it is to be relied upon for substantial long-term electrical generation contributions. Although existing plants supply about 13 percent of the country's total electricity demand, a vigorous government effort to find a scientifically acceptable and ecologically compatible solution to nuclear wastes, pollution, and potential health hazards is the key to eliminating the bottlenecks that threaten to halt further plant construction and even shut down current reactors.

The next section is devoted to a review of the use of coal. Substantial emphasis is being placed by the government to utilize this resource in much greater quantities. The United States has tremendous reserves of this resource; however, as with the nuclear option, the coal industry has many problems which need to be resolved.

Coal

Prior to the Industrial Revolution, coal had already become the most utilized source of fuel of British industry. Before 1700, industrial power came from animal power, wind and watermills. In the eighteenth and nineteenth centuries coal replaced wood in many processes. The expanding industrial utilization of coal led to increased demand for the fuel and, consequently, to improvements and innovations in the coal mining industry itself. Coal fueled the industrial revolution and is still very central for industrial processes (31:17-18).

One of the main attractions of utilizing coal as an energy source is its relative abundance. World-wide estimates of the reserves of coal range from 8-16 trillion tons; however, using current mining techniques and under prevailing economic conditions, only a fraction of the coal reserves is recoverable. It is estimated that under current conditions that the U.S. has between 150 and 200 billion tons of recoverable coal. U.S. reserves as shown in Table 3 lie at various depths below the earth's surface. "Current mining methods limit mining to a depth of 1000 feet and, therefore, limit the total recoverable amount of coal [31:93]."

Assuming a total recoverable resource of 200 billion tons of coal and the current recovery rate, supplies should be ample for several hundred years to come. The

TABLE 3

U.S. ESTIMATED COAL RESOURCES [31:93]

Depth of Overburden (Feet)	Type	Resources (Billions of Tons)	Energy Reserve (x 10^{18} Btu)
100	Strip coal	140	3.6
100 to 3000	Bituminous	959	
	Lignite	448	37.0
	Anthracite	13	
3000 to 6000	All types	337	8.8
6000 to 9000	All types	1313	34.1
TOTAL		3210	83.5

NOTE: Current mining methods are not economical below depths of 1000 feet.

problem with coal is not availability so much as it is a problem of environmental protection, safety in mining, and economic issues (31:95). Technological developments are needed to improve the utilization of this energy resource.

Until the 1960s any technological innovation in the coal industry was primarily involved in the mining operations. This development was rather fragmented but reasonably successful. It involved the participation of mining equipment companies, the U.S. Bureau of Mines, and operating firms. Several innovations were rapidly implemented including the shuttle car in the thirties and forties and continuous mining machines in the fifties. Traditional patterns of innovation are still prevalent;

however, the government, large coal companies, and foreign firms are now playing greater roles (88:102).

New innovation activities have been emerging which could improve coal's long-run prospects. On one hand, increased attention is being given to burning coal in a more efficient and cleaner manner. The other new direction for coal research and development is in the area of gasification and liquefaction.

One promising area for providing efficient and clean combustion of coal involves fluidized-bed combustion, in which a fossil fuel is burned in a bed of granular particles held in suspension in an air stream (88:102). The process offers the potential for reducing sulfur oxides while at the same time increasing boiler efficiency. This technology is potentially lower in cost than that of burning coal and using scrubbers.

Gasification and liquefaction are attractive uses of coal from a pollution standpoint. The current technology dealing with pollution from burning oil and gas is more developed and less expensive than dealing with pollution from direct burning of coal (88:102).

Liquefaction is one technique that is important in reducing our dependence on foreign oil. The Republic of South Africa has been actively involved in this technology for a number of years. As it saw its relations with its oil supplier, Iran, deteriorate, it quickly stored oil and began exploiting its vast supplies of coal. Coal liquefaction will provide about 35 to 50 percent of South Africa's total petroleum consumption by the early eighties (88:103).

Use of liquefaction or gasification plants in the United States has been discouraged from an economics standpoint. An engineering firm in 1976 found that synthetic gas cost from $3.88 to $6.72 per million BTUs compared to natural gas at $1.40 to $2.20 per million BTUs. These figures are becoming closer by recent developments in price escalations by OPEC (88:104). The cost difference may also be narrowed as a result of the phase-out of price controls on petroleum.

A new plan involving underground gasification of coal appears promising. This process is currently under study by the Department of Energy (DOE). The process involves drilling holes into a coal seam, establishing permeability in the seam, injecting air or oxygen to sustain gasification and withdrawing gas from neighboring wells. Since the energy is obtained without mining, most ash and sulphur contaminants remain underground. The gas can be combusted on site to generate electricity, be used as a chemical feedstock or be upgraded to synthetic natural gas (12:3).

Another technology receiving recent attention involves utilizing coal slurry to transport coal. Western states consider coal slurries which use water as the carrier to be wasteful and environmentally unacceptable; therefore, the Energy-transition Corporation (ETCO) is working on a plan to turn part of the West's low-sulphur coal into methanol and to use that liquid to replace water as the carrier in the coal slurry pipeline. Both the coal slurry and the methanol would be used as fuel at the end of the pipeline. The company's backers are so confident that their technology will work that they say the system would be in operation in five years. Under ETCO's conversion proposal each 4.4 tons of mined coal would produce two tons of pulverized coal for shipment and one ton of methanol. The remaining 1.4 tons would supply the energy used in the conversion and water contained in the coal would supply most of the process water. The coal-methanol mixture could be shipped to generating stations in the southeast or on the west coast and then separated. The coal would be used to feed a coal generating station and the methanol would serve as fuel for a combined-cycle gas turbine electrical generator (24:39-40).

Coal gasification is presently being considered by the military services. Bechtel National Inc. under contract to the Navy has shown that gasification plants could be economically attractive. Gas from a plant producing 250 million BTU/hr with a load factor of 90 percent was shown to have a lower life cycle cost than continued use of fuel oil (67:1-1).

The coal industry could become more conflict-ridden, with environmentalists fighting against the industry, the industry fighting the government and labor fighting management. This type of problem was exhibited in the coal strike of 1977-78 which lasted almost four months. The strike created distrust among workers and managers, left the union weaker and affected the stability. The environmental problems have been pursued through the National Coal Policy Project which has sought to achieve consensus and cooperation between the industry and the environmentalists. Some signs of progress are now apparent (88:106-107).

Summary

Despite its abundance, coal will probably not become our major near-term solution to the energy problem. Its use will grow since the government is pumping large amounts of money into the industry to encourage the development of new technologies. The strategy for utilizing coal should probably be to concentrate on long-term answers through technological innovation, while also seeking ways to use coal's short-term growth.

Many environmental and economical considerations need to be resolved before all citizens can be satisfied with substantial increases in the use of coal. Many new technologies are emerging which may resolve the majority of these problems.

The next section is concerned with our use of natural gas. Natural gas, like coal, has played an important part in the nation's growth but has shown a diminishing contribution in recent years. Technological solutions may provide the answers needed for greater exploitation of this resource.

Natural Gas

In 1977 natural gas constituted about 25 percent of the energy used in the United States or about 9.2 million barrels per day of oil equivalent (88:15). In 1974 gas accounted for about one-third of the energy used in the United States. Although the consumption of natural gas decreased from 1973 to 1975 by about 11 percent, this decrease was not due to decreased demand but rather to a reduced supply of gas. The present shortage did not occur suddenly but was part of a trend over the past two decades. While the consumption of gas was increasing over the past two decades, exploration and drilling activities for gas declined substantially (31:73). This was due in part to government price controls which made the endeavor uneconomical. An important measure of the availability of natural gas for future consumption is the known reserves of gas;

therefore, if new reserves of gas are discovered each year equal to the amount of gas consumed, a constant ratio of reserves to production is maintained. This ratio has dropped from 21 in 1956 to less than 15 in 1970 (31:73).

Richard Dorf states that it is difficult to estimate reserves but that estimates range from 1000 trillion cubic feet to 2000 trillion cubic feet. The current government accepted estimate of total gas reserves (in 1977) was 1845 trillion cubic feet, which includes offshore sources and Alaska (31:74).

Experts use two different approaches to answer supply questions. Economists typically estimate the supply that would result at various price levels. Geologists typically ignore price and relate supply to the size of recoverable reserves. Within both groups of experts there is disagreement (88:67).

In 1976 the General Accounting Office declared that few additional reserves would be discovered at prices above $1.75 per mcf. At the same time, the Energy Research and Development Administration estimated that a rise in the price of natural gas from $1.75 to $2.50 per mcf would increase U.S. recoverable reserves by 20 percent (88:67).

Geologists also differ in their opinions. In 1974 the U.S. Geological Survey projected sufficient gas supplies to last anywhere from 44 to 100 years at 20 tcf per year consumption rate. In 1977 the Central Intelligence

Agency estimated that the United States could continue to consume gas at the rate of 20 tcf per year for fifty to sixty years. In 1974 Shell and Mobil projected gas reserves to last only twenty to thirty years at "contemporary" consumption rates. In 1976 Exon estimated a stock which would be good for only fifteen to twenty years (88:67).

Although imports from the Middle East and Mexico are possible and conversion of coal to gas is attractive to meet our demand, several studies have shown that vast supplies of gas have yet to be exploited.

Almost all of the gas that has been produced and consumed has come from depths less than 15,000 feet. Gas is known to occur at deeper levels and this makes the question of gas supplies even more bewildering (88:68).

Below 15,000 feet gas is found in two types of formations. One is very deep porous sandstone. However, the deeper the well is drilled, the more it costs per foot. It has been common to find a cost of $5 million to drill and complete a gas well deeper than 15,000 feet, compared to a cost of $100,000 for a well only 3,000 feet deep. Uncertainty is also greater at deeper depths because little is known of the geology of the reservoirs (88:68). A second formation which provides gas at depths below 15,000 feet is geopressurized brine. Dealing with this formation is costly because very large volumes of water must be dealt with (88:68).

Another unconventional source of gas is in sedimentary rock with low porosity, such as coal and Devonian shale. Due to the low porosity of the rock, it must be fractured to allow the gas to migrate to the well. Although limited experience does not allow projections to be made confidently, observers believe that gas from this source is unlikely to make an important contribution to the U.S. energy supply any time in the foreseeable future (88:68).

There are those within the oil and gas industry as well as utility companies who believe that the real key to the nation's energy future lies in untapped gas-laden waters deep beneath the Gulf Coast. Some go so far as to scoff at the idea of an energy shortage and believe that the United States should convert to a methane society (14:9).

Dr. P. H. Jones, a hydrogeologist, has calculated the supply of geopressurized methane at 50,000 tcf in the states of Texas and Louisiana. Even though skeptics disagree somewhat with this figure, cautious government authorities are now coming around. In a recent U.S. Geological Survey Study, the estimate of this resource was expanded two and one-half times over its 1975 study (14:9).

President Carter's own "National Energy Plan II," estimated the recoverable resource at from 5,000 tcf to

63,000 tcf. Even the lower figure is nearly three times the highest total estimated resource base for the other forms of unconventional gas (14:9).

One of the most interesting developments is a plan by System Fuels, Inc., a wholly owned subsidiary of Middle South Utilities to use geopressurized methane commercially; however, exploratory work must be conducted first to prove out this new technology (14:9).

Another proposal expected to win approval by the Department of Energy is from Magma Power Company. DOE specialists say that Magma'a approach is more oriented to harnessing the heat from the great volumes of hot water that come up from the geopressurized zone. Magma plans to use all three energy sources--heat, methane and the mechanical force created when the high-pressured water burst to the surface (14:20).

Another good sign of this technology being further developed is the recent interest being placed in it by the major oil companies including Shell, Amoco, Mobil, Texaco, and Union. Meetings have been held jointly between the DOE and interested oil companies (14:22).

Summary

Although a wide range of opinions exist concerning the supply availability of natural gas within the United States, recent developments in geopressurized methane provide promise that this energy supply is available in quantities not dreamed of a few years ago. Since gas is one of the more desirable forms of energy available, it seems prudent that the DOE and the energy industry further the development of this technology. If current tests prove out, then our whole society may be influenced to change to a methane orientation and subsequently reduce our dependence on foreign oil.

The final section of this chapter is concerned with one of the most economical forms of energy generation--hydroelectric. Particular emphasis is placed on retrofitting existing dams and development of smaller generating sites.

Hydroelectric

Hydroelectric power is a vital source of electrical power not only in the United States but also for many Northern European nations.

> The total installed electrical generating capacity of the U.S. in 1972 was 418,000 megawatts, of which 54,000 megawatts, or 13 percent, was generated by hydroelectric generating plants [31:306].

A substantial drawback to the use of hydroelectric power involves the high initial cost involved in plant construction. The capital investment required to construct a new hydroelectric project can vary substantially depending on the size and location of the project, land acquisition, relocation of buildings and other cost. The average cost of construction of a new hydroelectric plant based on a per kilowatt comparison is higher than for a thermal electric plant. Hydroelectric power is still the least expensive power available since the plant requires no fuel; however, the initial capital investment ranges from $100 to $400 per kilowatt (31:210-211).

Traditionally, engineers have looked toward large-scale technology such as large hydroelectric dams, nuclear and fossil fuel power plants; however, since capital costs are so great and often environmental concerns are paramount, they have also begun to heavily explore the small-scale and alternative possibilities. The potential of combinations of solar, wind, methane and geothermal energy and of conservation practices to fulfill our demand for energy with minimal environmental impact and on a scale adaptable to local needs and to local control are now being included in discussions of future energy supplies. Missing from most of these discussions of "appropriate technology" is hydroelectric power (36:33).

In the 1920s, hydro supplied a third of the country's electricity. Today it supplies only 13 percent (16:43). At President Carter's request, the Army Corps of Engineers counted and evaluated all the dams in the United States. Of the 49,500 they found, less than 3 percent produced power. Most were used for flood control, navigation, irrigation, water supply and recreation, and a large number were just old and abandoned (16:43).

The Corps estimates that the installation of additional generating capacity at existing dam sites would add to the nation's power pool about 54.6 million kw--the equivalent of 85 good-sized nuclear power plants. Almost half of that power would come from tiny underdeveloped dams with capacities of less than 5,000 kw, while the rest would come from installing more powerful and efficient equipment at dams that already produce power (16:43).

New England's rugged landscape has two natural features in abundance: rivers and mountains. The potential for hydro power in New England is immense. There are more than 2,800 dams in the six states of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut; however, only 200 of them produce electricity, many far below their full capacity. At the other 2,600 dams, water simply pours over the top, wasting the potential for efficient use of the energy thus created (86:17).

A boost for the development of small dams has come recently from Congress. Low interest loans will be provided to encourage the redevelopment of existing dams of less than 15 mw of capacity (86:17).

An innovative and complicated plan is underway for a new hydroelectric project in Springfield, Vermont, a community of about 10,000 people. At the center of the plan--

and at the center of the town itself--is the Black River, which drops 120 feet in less than one mile as it passes through the deep valley lined with factories. When the factories were first built, their machines were powered by Black River water channeled through turbines in a series of dams. But factory managers followed the trend all over New England after World War II and brought in cheaper electricity from outside. The dams and turbines were taken out of service (86:18). The new plan calls for the installation of new hydroelectric power generating equipment on three existing dams in the industrial valley and on a fourth dam up stream. Altogether sixteen miles of the Black River would be harnessed to produce 30 mw in a peaking power system that would supply Springfield with all its power, with the rest to be sold to other Vermont utilities (86:18).

In July 1977, Ted Larter, an enthusiastic proponent of water power, and a partner bought a small, unused hydroelectric plant at Goodrich Falls in Bartlett, New Hampshire. The equipment was being auctioned by the town officials and was acquired for a cost of $52,000. It took another $35,000 to restore the plant to operation; however, by October 1977, the plant was operating again, feeding an average of 300 kw into the Cooperative's Mount Washington Valley grid--enough power to provide electricity for about ninety households (86:18).

What is especially true in New England is also true of other regions in America. There is hardly a state without potential in waterpower or where waterpower is being used as fully as it ought to be (60:85). Small and medium sized projects can be developed throughout the United States at a lower capital cost per unit, and will produce energy at a lower production cost per unit than we are likely to get from huge new generating stations using less permanent, less reliable, more hazardous resources; moreover, they can be built quickly, compared to the 10 to 12 years required to design, license and build a large coal-burning or nuclear plant (60:85).

Despite its advantages and vast potential, small hydro plants have problems; i.e.:

1. Many dams are old and need repair.

2. Silting has probably cut reservoir capacity in at least 16 percent of the nation's dams (16:43).

3. About 60 percent of the nation's dams are on streams that dry up for one week to six months almost every year.

4. Some dams preclude hydro development, as can be the case with residential, irrigation, industrial, flood control, recreational and water control dams.

5. Licensing by the various municipal, state and federal boards can be very time consuming (16:43).

Central to the potential for new ways to use existing dams and also non-dam hydropower is the development of relatively new technologies of tube and bulb turbines (36:34). The bulb turbine is simply an adaptation of the waterwheel-generator combination. "It is named for the bulb shaped housing which protects the generator [36:34]." The advantage of the bulb turbine is that it can be placed in an aqueduct, pipe or tied into dams or other water controlling systems.

Although less flexible than the bulb turbine, the tube turbine works in the same general manner. The primary difference is that the tube turbine's generator is not encassed in a submersible housing (36:34).

It is estimated that by the use of retrofitting and improving existing dams, by the use of turbines such as the tube turbine and the bulb, that over 25 million kilowatts of additional electric power could be provided nationwide.

Summary

Although the additional energy produced by small and renovated hydroelectric sources will not eliminate the need for other power generating sources, their contribution to providing cheap and reliable electrical power will be substantial. Hydropower can play an important role in combination with other small-scale energy projects such as solar, wind and methane. Any increase in energy supply from these clean renewable sources means a reduction in the demands made on the other, non-renewable and more hazardous, fossil fuels and nuclear power sources.

Hydroelectric power provides a substantial contribution to the nation's overall electrical energy production. Large hydroelectric dams are increasingly becoming cost prohibitive due to construction cost as well as land acquisition cost. In addition, few ideal locations remain in the U.S. for large dams. The near-term emphasis for hydroelectric growth will probably be concentrated on retrofitting and improving existing dams and developing small generating plants.

Chapter Summary

Energy has played an essential part in the development of civilization. The usage of energy forms has evolved over the centuries to the point that most economies became primarily dependent on fossil fuels for their continuing development.

In the United States, a tremendous dilemma has arisen during the past several decades. Continued economic growth coupled with diminishing domestic supplies of petroleum and natural gas, greater concern for the environment and higher dependence on imported oil have contributed substantially to a national vulnerability.

Currently the main sources of domestic energy supplies other than oil, are nuclear, coal, natural gas and hydroelectric. As oil supplies continue to diminish, our country has been faced with dependence on these other energy sources to regain some level of national energy independence. Each alternative is plagued with environmental, economical, technological and political problems.

No single energy source can offer the energy solution for the United States or the Air Force Logistics Command. Energy self-sufficiency for AFLC may involve the greater reliance on these conventional energy resources, especially if they are abundant in the geographical region of a particular Air Logistics Center.

It is becoming imperative that a coherent national energy policy be developed which will optimize the utilization of these conventional resources as well as providing for the continued development of new or unconventional technologies. Current national policies as well as the Air Force policies are among the topics discussed in the next chapter.

CHAPTER III

ENERGY POLICY

Introduction

"The national security, financial stability, and standard of living of a nation are interwined with its energy consumption [31:433]." International events have made many nations aware of the fact that domestic inflation and related economic factors, adjustments in life style, and national security can be challenged and impacted by the reduced availability of energy supplies. Many nations are attempting to determine what energy and environmental policies are required in order to balance supply and energy consistent with acceptable economic, social and environmental goals (31:433).

Continuing with the analysis of the "Energy Self-Sufficiency System," this chapter addresses the subject of energy policy. This topic is analyzed from the National, Department of Defense, Air Force, and Air Force Logistics Command levels. Specific issues which affect policy have been identified and discussed. The concept of national "Energy Independence" is of particular interest in this chapter.

National Policy and Energy

In response to the 1973 Arab oil embarbo, President Nixon on November 7 of that year, called for a crash energy program. President Nixon's first steps were to resolve the immediate "crisis" by directing industries and utilities to use coal, reduce the temperature in buildings, reducing speed limits, speeding up the licensing and construction of nuclear plants, and introducing energy conservation legislation into congress. Secondly, the President called for the United States to "unite in committing the resources of the nation to a major new endeavor in this Bicentennial Era we can appropriately call 'Project Independence' [69:100]." "Project Independence" was to make the United States self-sufficient in every resource by 1980. However, it was determined that complete independence by 1980 would be costly and impractical. A study made in 1974 reported the total independence effort would cost more than $400 billion and possibly as much as $600 billion (74:168). Another study made by the University of Houston under sponsorship of the National Science Foundation indicated that energy independence could possibly be reached by 1985 if price controls on coal, oil and natural gas were lifted; no further increases in oil and natural gas in industrial or electrical generating plants were allowed; nuclear and hydroelectric power could supply 25 percent of the country's electricity by 1985; and population growth is controlled at an annual rate of 1.2 percent and real per capita income increases held at 1.8 percent (74:69-70). While independence is still possible, it cannot occur by 1985 due to delays in the recommended programs and other political and technological considerations.

President Ford continued to support the concept of energy independence and proposed legislation to establish an Energy Independence Authority. In his 10 October 1975 letter to the Speaker of the House of Representatives and the President of the Senate, President Ford reiterated the problems associated with an ever-increasing dependence on foreign oil. President Ford noted that two years had passed since the Arab oil embargo and that the country's vulnerability had actually increased. Ford stated the following (42:1151-1152):

> Nearly nine months ago I asked the Congress to adopt the Energy Independence Act of 1975. Prompt action on this proposal would have provided the statutory framework necessary to achieve energy independence by 1985. Enactment of this legislation remains as crucial now as it was in January. I urge the Congress to complete action promptly on these proposals.

Ford's letter pointed out that capital requirements would total about $600 billion over a ten-year period to achieve energy independence and was concerned that private capital markets would not provide the necessary financing. He believed that uncertainties associated with new technologies would inhibit the flow of capital. Ford continued (42:1151-1152):

> America cannot permit the excessive delays associated with the commercialization of unconventional energy technologies. Our national security and economic well-being depend on our ability to act decisively on energy.

Ford's Energy Independence Authority Act of 1975 would have created a partnership between the private sector and the federal government to assure action on vital energy projects for the decade of 1975 to 1985. The legislation also addressed the need to simplify and expedite the process by which energy development was authorized. He proposed a more effective federal licensing process by authorizing a coordinated, single federal application process which would have required federal agencies to act promptly (42:1151-1152). Unfortunately, most of Mr. Ford's initiatives were not favorably considered by members of congress and other ideas were delayed.

Presidents Nixon's and Ford's proposals for energy independence have been discarded or at least postponed. President Carter in his 15 July 1979 speech to the nation made it clear that, in the short run at least, the emphasis of a national energy policy will be on conservation and improving energy technology rather than gaining total energy independence. President Carter's energy plan placed a quota on oil imports at no more than the 1977 levels;

proposed the creation of an Energy Security Commission to lead an effort to develop alternative energy sources which would replace two and one-half million barrels of imported oil per day by 1990; asked Congress to legislate a required 50 percent cut in the nation's utility companies' use of oil and proposed the creation of an Energy Mobilization Board with the responsibility and authority to expediate key energy projects (21:129). The President's plan seems to lead to a reduced dependence on imported energy supplies, and could lead to independence in the long run.

Many questions arise when an attempt is made to define what the energy policy of the United States should be. Some questions that are currently debated include (31:434):

1. Should the United States pursue the policy of self-sufficiency in energy resource development and production?

2. How dependent should the United States be on imported petroleum?

3. Should the United States pursue ways to negotiate contracts that would guarantee delivery on imported natural gas?

4. Should monetary and fiscal policies be designed to provide increased incentive for the development of potential energy reserves?

5. Could synthetic fuels close the energy gap?

6. What are the air quality aspects of greater use of low sulfur oil, high sulfur oil, and coal?

7. Should the nation encourage policies to alter building codes that would reduce energy demand?

8. How can the energy demand from the transportation sector be lowered?

Some of the policy implementation problems being debated include (31:434):

1. Are clean energy, national security and a low-cost national energy base compatible?

2. Should the price of energy be allowed to be set by the free market system?

3. What are the implications for siting refineries in connection with deep-water terminals to receive imported energy supplies?

4. Should there be a "one-step" approval procedure for energy-related projects?

5. Should a coordinated federal-state energy research and development effort be established?

A number of energy advisors believe that the overall objective of the United States energy policy should consider (31:434):

1. The development of a supply of energy which is adequate and priced at reasonable levels to enable the nation to enjoy a good standard of living.

2. The attainment of "relative self-sufficiency" of energy supply.

3. The maintenance of a healthy and safe environment.

4. The achievement of optimum efficiency in the production, distribution, and utilization of energy.

5. The reduction of demand for energy and the conservation of energy resources.

Newsweek, in an in-depth analysis conducted last summer, had some suggestions to guide the country in developing an energy policy. They conceded that energy may never again be cheap and that Americans may not be able to produce enough of its own energy to be self-sufficient; however, National energy policies can pave the way to a more secure and balanced energy future (115:25). The main goal should be to reduce U.S. dependence on imported oil while making the transition with minimum shock to the economy, the environment, and to the American way of life. This represents a very large task. Newsweek believes that this can best be accomplished by allowing the free market system to allocate the resources rather than government bureaucracies. They recognize that some tradeoffs on environment, economic and social issues will be necessary if the United States is to achieve its long-range goal. They believe that energy policies must be wide-ranging, flexible and resilient enough to retrieve error. "There is no one solution to the energy crisis, merely a chance to guarantee that national policy will provide a more secure future [115:25]."

Mark J. Berman of Houston Oil and Minerals Corporation writing in Business Economics believes that ". . . the world is walking on an energy tightrope. If both conservation and productions are not enhanced, it [the world] is likely to fall off [10:37]." Berman believes that the United States cannot feel too secure beyond the 1980 timeframe. He believes that there will be a continued compound growth in energy demand and even at subdued levels, the limits of the world's resources will probably cause a flattening in oil production around the turn of the century.

> Alternate energy sources must be available to provide for any growth in total energy consumption. To prepare for this, increased emphasis must be placed on the development of all energy sources, from oils to the exotics [10:37].

Berman believes that counterproductive "meddling" in the energy business by governments must cease so that supplies of oil can be freely transported to demand, and so that investment in alternative energy is encouraged. "Otherwise, shortage is likely before the end of the century [10:37]."

John E. Swearingen, Chairman, Standard Oil of Indiana, noted at the International Monetary Conference held in London in June, that the end of the decade marks the official end of an era of cheap and overabundant energy. He warned: "With the advent of the 1980s, we enter into an era of high energy prices, tight energy supplies and chronic worldwide shortages [51:21]." Mr. Swearingen believes that during 1980-1985 reliance of the industrial world on imported oil will continue to increase even though supplies will never be so abundant as ten years ago. He said that over the short term, the United States must try to reduce consumption by 5 percent, as has been pledged by member nations of the Internal Energy Agency. "To do so, a number of politically unpopular steps must be taken, including decontrol of prices of domestic oil [51:21]." He believes that the national interest is better served when it coincides with individual self-interest, and the pricing mechanism assures direct personal involvement (51:21).

Time magazine noted recently that with turmoil spreading throughout the oil-rich Middle East, it hardly seems the time to put energy on the back burner. "Yet, just when Jimmy Carter should be pushing hardest to cut consumption and conserve supplies, he seems to be taking a surprisingly soft approach [79:62]." Until recently, the Administration had shelved plans for a $5/bbl. tariff on foreign crude and had also backed off on calling for a steep new gasoline tax. Instead of building upon the national sense of urgency, top Administration officials were arguing that these tactics were not really needed.

They believed that imports had begun to slow and consumption of gasoline to decline. It appears that as one Energy Department official noted: "Energy for 1980 is going to be spelled N-O-V-E-M-B-E-R [79:62]." If a fuel shortage does develop, President Carter may call for nationwide gasoline rationing and imposition of the new tax. The Administration now seems inclined to switch away from its original plan to take all revenues from the oil windfall profits tax and use them for energy development, mass transit, and help for the poor to pay their energy bills. "Instead, the idea now is to spend much of the money on a broad range of federal programs [79:63]." One high Administration official states that the windfall profits tax is going to raise more money than is needed. "Our concern now is that the money is not tied up [79:63]." This charge could incite new debate in Congress over the windfall profits tax and delay passage of Carter's energy program.

> In sum, the present U.S. energy policy depends largely on the voluntary conservation by the American public and a hope that the oil-producing countries will continue their current levels of output without unforeseen interruption [79:63].

Peter Metzger writing for Industrial Development believes that a group of Utopian activists want to "turn off" the nation's economy and to "bring the whole country to its knees [65:2]." Metzger believes that President Carter, in what has to be regarded as a sincere effort to improve upon the Nixon-Ford approach to social justice, environmentalism, consumerism, growth and energy issues, made a fatal mistake for the nation. Instead of appointing people with prior experience and knowledge in managing these issues, Carter's main criterion for filling these key jobs has been that his appointees must have distinguished themselves in their particular fields by protesting the former administration's policies, either in the courts, on the streets or in the press (65:2).

> Like many Americans, the President assumed that those who were good at protesting knew a better way, and if taken into government and given the chance, would create that better way of doing things. But as it turns out, the protestors' better way is to stop--not control wisely--the development of everything a nation needs to grow [65:2].

Metzger believes that for the first time in history, those in power have decided that the goose has laid enough golden eggs, and is going to be retired. Metzger calls these leaders "coercive Utopians."

> That they are Utopians is self-evident, but that's no crime. After all, many of us are or were, at least, ourselves Utopian. But, the difference between classic Utopians and these is that instead of convincing the public that their vision of tomorrow is so attractive we ought to move their way by normal democratic means and convinced by their good example, they are doing it covertly and; therefore, coercively [65:3].

It has been noted by many energy analysts that the March 28, 1979 accident at Three Mile Island nuclear power station may have spelled the demise of the nuclear energy future in the United States. Metzger believes that Carter's-appointees had already killed the nuclear option two years before the accident by studying it to death (64:4). One might say that nuclear is controversial but surely coal should be well on its way to help our energy situation. Most people are shocked to learn that no new federal coal leasing will be permitted until at least 1981 and active mining will not occur until much later. There are 519 existing federal coal leases in the seven western states but 95 percent were issued prior to 1970 and that means before the passage of (65:4):

- The National Environmental Policy Act of 1970
- The Clean Air Act of 1970
- The Clean Air Act Amendments of 1977
- The Clean Water Act of 1972
- The Clean Water Act Amendments
- The Coal Leasing Act Amendments of 1976
- The Surface Mining Control and Reclamation Act of 1977
- The Critical and Endangered Species Act of 1973
- The Safe Water Drinking Act of 1974
- The Solid Waste Disposal Act of 1971
- The Federal Water Pollution Control Act Amendments of 1972
- The Mine Safety and Health Act
- The Mine Safety and Health Act Amendments of 1977
- The Resource Conservation and Recovery Act of 1976
- The Coastal Zone Management Act of 1972 and the new Wetlands controls
- The Fuel Use Act of 1978
- Public Utilities Regulatory Policy Act of 1978,

not to mention other federal and state legislation, and a host of rules and regulations of numerous agencies of the federal government such as BLM, USGS, EPA, CEQ, the Corps of Engineers and others. Also, many new rules and regulations are coming, and new agencies, such as the Office of Surface Mining (OSM), are just getting into business.

Obviously, the laws, rules and regulations applicable to coal mining today are considerably different from those which existed prior to 1970 when 95 percent of the existing leases were issued. So, there's a squeeze-play for you: Existing leases may not be legally mineable today and new leases don't exist at all [65:4].

This argument could be followed further, but it is sufficient to note Metzger's bottom line: conventional means to meet energy demands are discredited with scare tactics and denounced as morally unacceptable degradations to the environment. When the energy shortages do finally occur, and massive unemployment and social disorder inevitably follow, the corporations, capitalism and representative democracy itself will be blamed by those vocal coercive Utopians for problems that only Nader's "consumer owned economy" can solve (65:7).

The purpose of U.S. energy policy should be the managing of a transition from a world of cheap imported oil to a balanced system of energy sources (88:216). A highly regulated system is not the answer to our energy problems. Without a transition to a balanced energy program, regulation and disruption will constrain the market system itself more and more. Although both incentives and sanctions have a role, the emphasis should be on incentives. "The carrot makes for better politics and more acceptable change than the stick [89:71]." If energy independence is to ever be achieved, government policy must be changed and the trend toward overregulation halted.

The following sections are concerned with current energy policy at the Department of Energy, Department of Defense, Headquarters Air Force, and Air Force Logistics Command levels.

Department of Energy Policy

Speaking before the committee on Science and Technology of the U.S. House of Representatives on January 31, 1980, Energy Secretary Charles W. Duncan, Jr. presented the Department's Posture Statement. Mr. Duncan noted that the mission of the Department of Energy[6] (DOE) is to assure the "nation's orderly transition from an economy dependent upon oil to an economy relying upon diversified energy sources [29:1]."

The department believes that the transition in energy usage will occur in three phases. During the next five years the world will continue to depend heavily on oil. During 1979, oil supplied about half of the world's energy. The most readily available and most economic source of additional energy in this initial period is conservation, or the more efficient use of the energy now being consumed. Additionally, the use of coal, uranium, and natural gas can help reduce the growth of demand for oil. The DOE also believes that some non-OPEC nations such as Mexico and the United Kingdom will increase their oil and gas production (29:1).

In the medium term (1985-2000), DOE anticipates that the world will begin to make a significant move away from oil dependence. During this period, the attractive

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[6] DOE's organizational structure is presented in Figure 4 (96:B9).

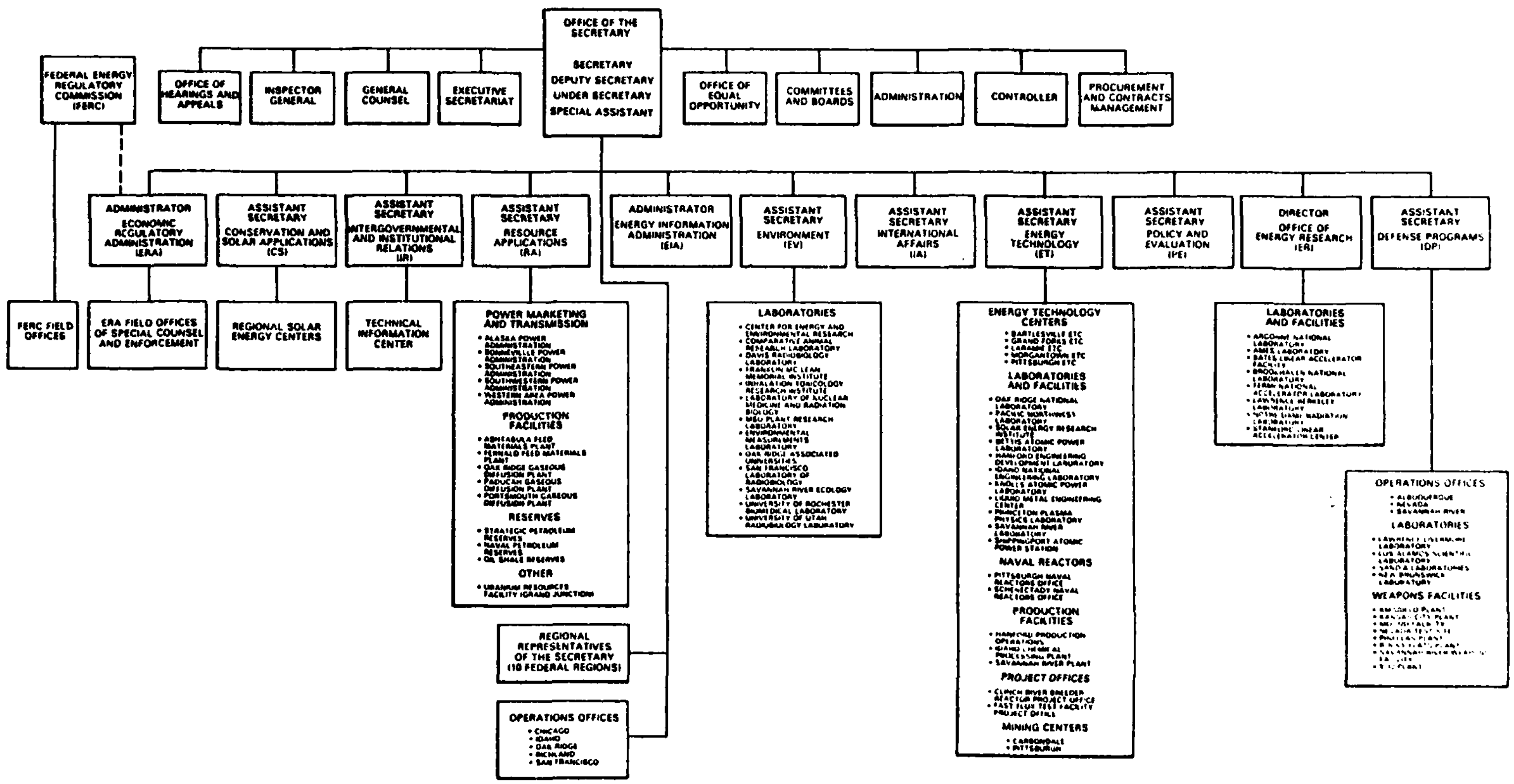

Fig. 4. **DEPARTMENT OF ENERGY ORGANIZATION** [94:A-2]

options for reducing the demand for oil, and diversifying its energy supply will include

> . . . more coal and coal-derived synthetic fuels, solar technologies, oil shale, unconventional gas supplies and nuclear power as well as continued improvements in the efficiency of energy use [29:1].

Past the year 2000 the world will rely more heavily on renewable energy sources and advanced nuclear technologies. DOE recognizes that although these technologies will displace both traditional fuels and non-renewable unconventional sources of energy, improvements in cost and technical performance must be achieved before they can be widely used.

> The Department's assessment of the world energy outlook demonstrates that, for many decades ahead, we must pursue efforts to expand and diversity supply with equal diligence. No single energy source, no single restraint on demand and no single technological innovation can resolve our current energy problems. Their resolution can come only by the pursuit of many distinct and sometimes complicated programs, unified primarily by their common need for full cooperation of all branches of government and for the long term support of sectors of the American public and economy [29:1,4].

This section has provided a brief summary of the DOE's perception of world energy usage and their policies which are directed at transition away from a primary dependence on oil. The following section is a discussion of the energy policies and management of the Department of Defense.

The Departments of Defense and Energy

The Department of Defense (DOD) uses 1.9 percent of the national energy consumption through direct usage. When related industries are considered, this percentage is increased to 5 percent. DOD is the largest single U.S. energy consumer and is by far the largest federal government user. This relationship is shown in Figure 5.

Since the DOD has felt a severe budgetary impact due to increased energy cost, it must operate nearer to the readiness margin than is desired. It is essential that all elements within DOD use available energy resources in the most efficient manner (93:9).

DOD energy management priorities reflect national goals as reflected in Executive Order 12003 shown as Appendix B.

Not only is the DOD energy management program designed to reach the national energy goals and objectives that have been mandated by the congress and the President, but it is also designed to achieve greater energy self-sufficiency, reduce energy cost, and ensure the operational readiness of our armed forces (17:287).

For 1980 the DOD energy management actions are categorized into four energy management priority groups (17:228):

1. Group I (Energy Supply Assurance). Actions within this priority are concerned with energy supply and procurement. Their primary purpose is to lessen DOD's

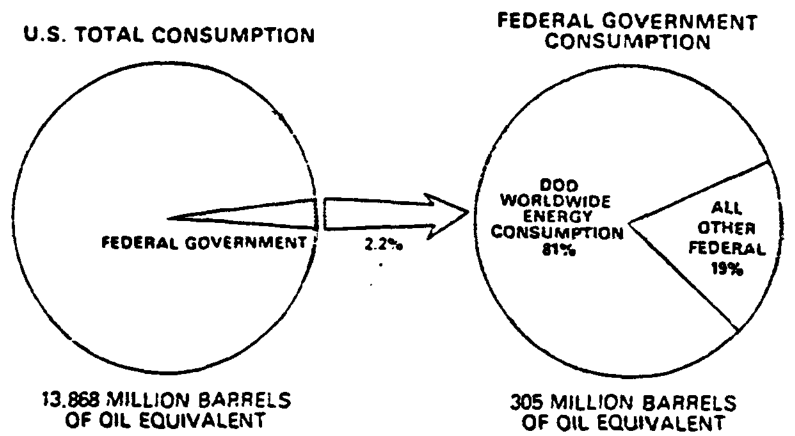

Fig. 5. Energy Consumption--FY 1978 [93:10]

vulnerability to energy supply disruptions. Specific actions will provide (17:288):

--Completion of policy and regulatory initiatives to provide prompt priority allocation to DOD of energy supplies during periods of supply disruption;

--Revised policies and procedures to increase energy supply flexibility, such as simplified contracting procedures, innovative acquisition strategies, and fewer stockage constraints;

--A DOD petroleum products stockage policy and a program to eliminate storage capacity deficiencies.

2. Group II (Energy Conservation). Program emphasis in 1980 will (17:288):

--Provide DOD energy management comprehensive visibility over the entire DOD energy conservation program;

--Reduce overall energy use through efficiency improvements without compromising flexibility, readiness, or performance; and

--Provide major improvements in the DOD energy data base by developing measures of progress towards Presidential and DOD energy conservation goals, and the correlation of expenditures for energy conservation efforts with energy conservation performance.

Motivation of DOD personnel to improve energy conservation will be pursued through incentive programs designed to recognize and reward, through monetary and non-monetary means.

3. Group III (Mobility Fuels Technology). DOD plans to pursue the long-term fuel transition technology which will emphasize liquid fuels from oil shale, coal and tar sands rather than petroleum.

The major thrusts of the DOD synfuels program are directed toward the application and, when necessary, the development of specific technologies that will enable DOD to (17:288-289):

--Encourage, in cooperation with DOE, the development of a commercial domestic synthetic fuels industry, capable of producing fuels for military use;

--Use domestically produced synthetic fuels and alternate conventional fuels in military mobile systems;

--Achieve an adequate degree of energy self-sufficiency for military installations through reduced dependence on petroleum fuels; and

--Develop a family of military engine systems that are capable of burning a broad range of both synthetic and conventional fuels.

4. Group IV (Energy Technology Demonstrations Initiatives). Implementation of the joint DOD-DOE energy initiatives which were begun in 1979 will be continued in 1980. By demonstrating a wide variety of energy conversion technologies it is believed that the nation will appreciate their application and practicality and ultimately reduce DOD's reliance on the scarce fuel sources. High priority will be given to the demonstration activities at the three DOD "showcase" installations. "The Defense Energy Managements Program is a major element of the overall program to reduce the federal government's energy consumption [17:289]."

"Longer term DOD energy goals cover operational energy usage in installations, training, and tactical and strategic forces [93:10]."

Achieving the United States national security objectives is possible only if the country is thoroughly prepared to meet essential industrial and military requirements (93:10).

> Attaining these objectives--deterring armed conflict, producing modern weapon systems, and maintaining the readiness of U.S. military forces--depends on all forms of available energy, particularly liquid fuels, to support worldwide commitments on the seas, in the air, and on the ground. In view of both the long lead times required to develop alternative energy sources and the rapidity with which currently used energy sources are being exhausted, the transition must begin immediately [93:10].

The principle DOD energy conservation officer is the Assistant Secretary of Defense (ASD) for Manpower, Reserve Affairs and Logistics (MRA&L). The focal point for all DOD energy matters is the Deputy Assistant Secretary of Defense (DASD) for Energy, Environment and Safety (EES). Responsibility for policy formulation in matters of energy conservation, management, supply, and technology applications rests with the Director for Energy Policy (DEP) under the DASD (EES).

> The Defense Energy Policy Council (DEPC) provides the DASD (EES) with the means to coordinate energy policy at the highest level as well as contribute valuable feedback on energy programs and problems. The DEPC comprises senior staff elements in the Office of the Secretary of Defense, the energy focal points of the military departments, the organization of the Joint Chiefs of Staff, and the Defense Logistics Agency [93:37].

The Defense Energy Action Group (a lower level group), enables the DEPC to develop energy policy.

There are two other elements in the Office of the Secretary of Defense involved with energy conservation through their program management responsibilities (93: 27-38):

* The DASD for Installations and Housing (I&H), also a deputy to the ASD(MRA&L), provides overall project management of the military construction program. In this capacity, the DASD(I&H) is the focal point for the energy conservation investment program (ECIP).

* The Office of the Under Secretary of Defense for Research Engineering has management responsibility for research and development and the energy conservation and management (ECAM) program.

Special assistants for energy matters as well as an energy office have been established within each military department.

> In each of the military services, commanders at all levels are responsible for the development and maintenance of effective energy programs. Figure [6] outlines energy management responsibility in DOD [93:38].

This section has concentrated on DOD energy policies and management. The next section will provide some insight into the specific policies of the US Air Force.

The Air Force and Energy

Secretary of Defense Harold Brown, speaking before the House of Representatives in June 1977, stated:

> There is no more serious threat to the long-term security of the United States and to its allies than that which stems from the growing deficiency of secure and assured energy resources [95:11].

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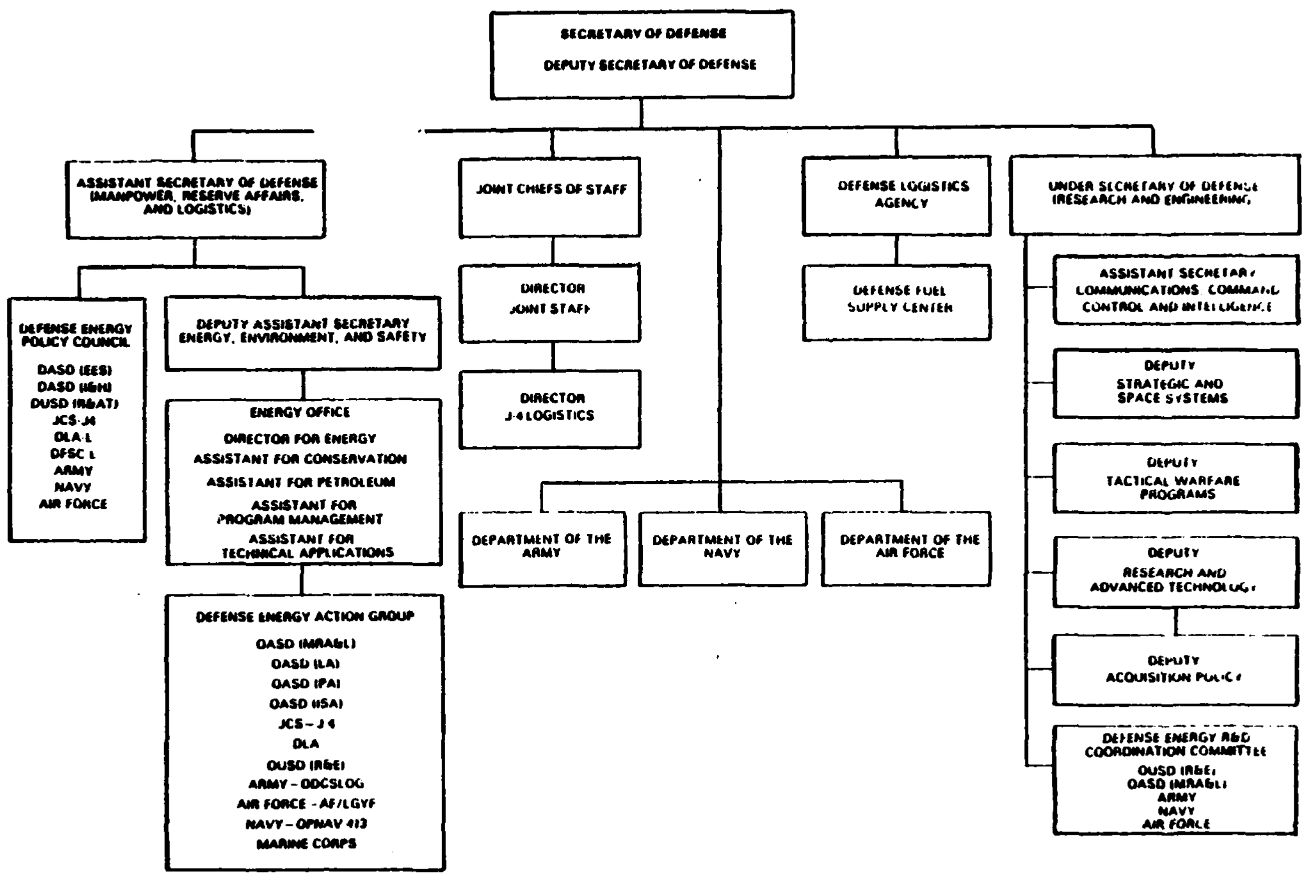

Fig. 6 DEPARTMENT OF DEFENSE ENERGY ORGANIZATION [95:C-2]

During the same year the Air Force consumed about 126 million barrels of oil equivalent (BOE), or about 690 trillion British thermal units (BTU) of energy at a cost of $2.1 billion. To support the Air Force and its missions, industry consumes a like amount of energy (95:11).

In 1976 the Air Force's consumption of JP-4 (kerosene base aircraft fuel) constituted 1.4 percent of the total U.S. petroleum consumption. If the Air Force were to rely only on domestic crude oil for secure JP-4, it would require 8 percent of the crude produced in the United States. During wartime this figure might be as high as 20 percent (95:11).

Continued reliance on petroleum products by the Air Force will increase its vulnerability and threaten its ability to accomplish mission requirements. As mentioned previously, the rate of oil imports is about one-half the total U.S. petroleum consumed. The gap between petroleum consumed and produced continues to widen and the Air Force is placed in the position of competing for this scarce resource. This demand-pull action results in ever-rising petroleum cost.

The U.S. Air Force Energy Plan notes that: "From FY1978 through FY1985, Air Force energy cost will rise an additional 22.7 percent to $2.578 billion, while consumption will remain about the same[7] [95:12]." To reduce the nation's dependence on petroleum-derived fuels, President Carter established national energy objectives in April 1977. The objectives involved reducing dependence on foreign oil, limiting supply disruptions, planning for declines in world oil supplies and developing renewable energy sources. In July 1977 the President issued Executive Order 12003 which established these objectives as requirements for each federal agency.

The U.S. Air Force Energy Plan of July 1978 was prepared to present its objectives and programs as well as national and DOD energy goals.

The current energy program guidelines include the following:

[1] Maintain energy consumption for all activities at the lowest possible level consistent with mission requirements and operational readiness.
[2] Demonstrate the use of alternative fuels for aircraft and base operations and eventually establish a multifuel capability for all Air Force systems.
[3] Review operational and training procedures to ensure that more plentiful energy sources are substituted for rapidly depleting resources where feasible.
[4] Cooperate with federal agencies in the demonstration and application of new energy technologies.
[5] Apply the principle of "energy effectiveness" to future engineering developments and system acquisitions in terms of return on investment or life-cycle cost [95:2].

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[7]This cost will probably be closer to $4 billion since the cost of JP-4 has recently increased from $0.55/gallon to $1.18/gallon.

An energy management program has been established to insure that the national and DOD objectives and requirements as well as those of the Air Force are met. The program is based on the policy that all energy actions must be realized through the Planning, Programming, and Budgeting System (PPBS). All energy actions must compete with other programs for funding.[8] The Air Force Energy Organization is portrayed in Figure 7.

Accomplishment of the Air Force energy objectives is centered around three programs; energy conservation, alternative fuels and advanced energy technology.

"The Air Force energy conservation program is directed toward reducing energy consumption without degrading military readiness [95:4]." The program affects not only facilities but also aircraft and vehicle operations. Energy conservation concentrates on reducing or eliminating levels of activities and operating more efficiently. The objectives of the conservation program are numerous. Present programs include an education program, flight hour

[8]Personal experience of one of the researchers with managing a Major Command's Military Construction Program (MCP) has been that competition for funding of all types of projects is extremely keen. Only a very small percentage of the projects submitted to Headquarters Air Force for review will ever be submitted to the Office of the Secretary of Defense (OSD), and an even smaller number will eventually be reviewed by Congressional Committee. Since energy-related projects must compete with new mission, mission support, continuing mission requirements, and other high priority projects, they must be economically attractive to even be considered.

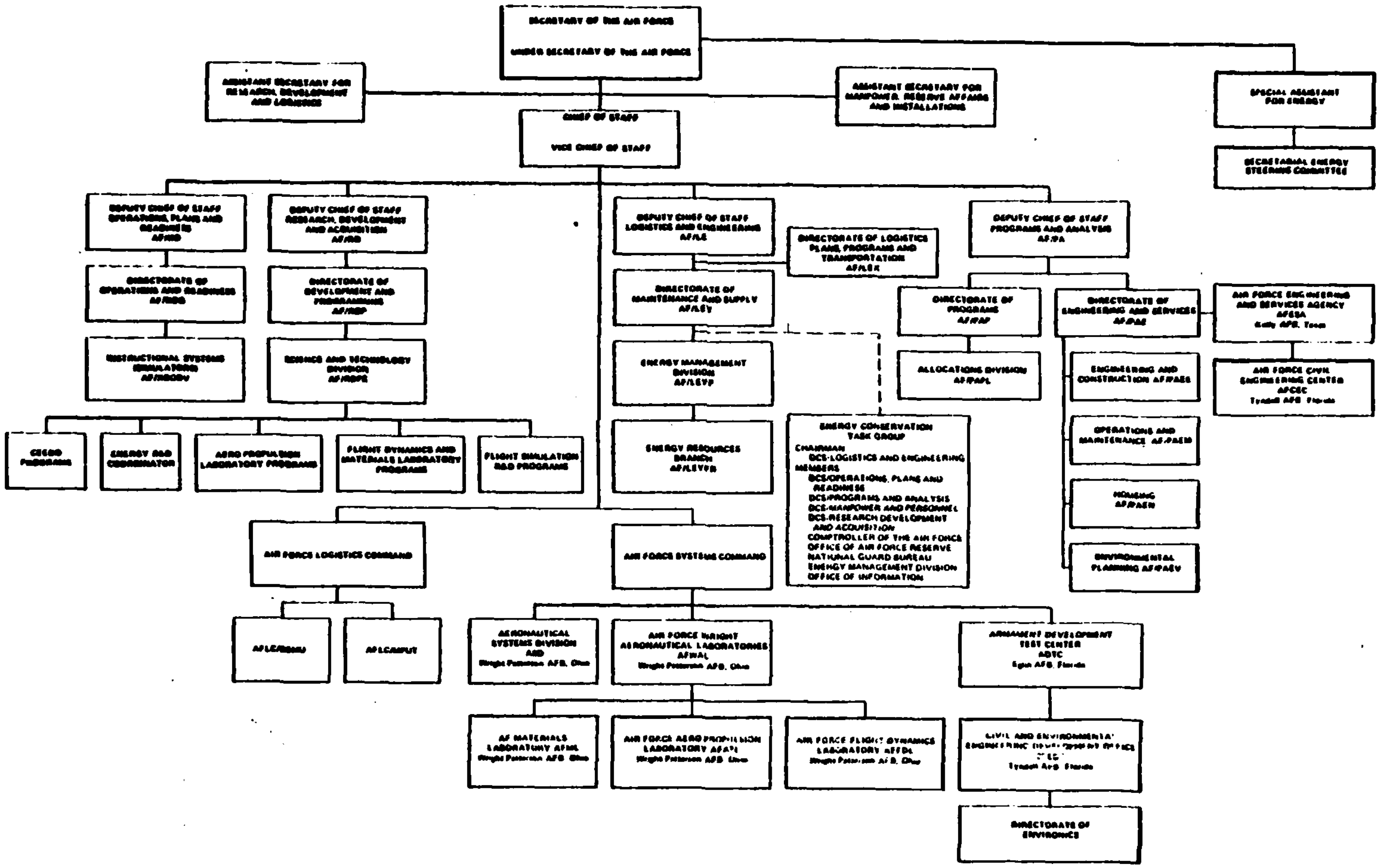

Fig. 7. **DEPARTMENT OF THE AIR FORCE ENERGY ORGANIZATION** [95:20]

planning, use of simulators, energy monitoring and control systems and others[9] (95:4).

The Air Force plans to develop alternative sources of liquid hydrocarbon fuels. A multifuel capability is required that will allow the use of synthetic fuels derived from sources such as oil shale, tar sands and coal. The Air Force in coordination with the Department of Defense (DOD) and Department of Energy (DOE) will participate in the development of synthetic crudes. Presently the Air Force alternative fuels program includes construction of coal-fired plants, use of waste lubricants and contaminated fuel, use of refuse-derived fuel, conversion of oil and

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[9]The Air Force Energy Conservation goals for FY 80 are as follows (104):

A. Aviation Fuels: Overall Air Force goal is zero growth from FY 75 consumption. Command goal is that quantity necessary to support the approved flying hour program.

B. Automotive Fuels and Diesel for Operations: For 1st and 2nd quarters, five percent reduction as compared against FY 79 consumption. For 3rd and 4th quarters, zero growth in consumption as compared against FY 79 consumption.

C. Facility Energy: 20 percent reduction in BTU per square foot by 1985 as compared against FY 75. Goal for FY 80 is an additional reduction of two and a half percent over FY 79 goal (5 percent reduction) for a cumulative total of seven and one half percent reduction as compared against FY 75.

The special 5 percent presidential goal (5 percent reduction in gross consumption for period 1 Apr 79 through 31 Mar 80), is a separate effort from this FY 80 goal and the two goals are not additive. If the Air Force goals are achieved, then the presidential goals will be satisfied in mobility fuels, and in most cases, will be satisfied in facility energy.

gas plants to coal and related research and development programs (95:5).

Efforts in advanced energy technology involve the use of renewable energy sources such as solar, wind and geothermal. These sources will be evaluated where feasible on the basis of cost and resource availability. These activities will be limited to specific technologies which show a high degree of potential for supplying an economically significant portion of the energy for a particular base (95:6).

To build a well-integrated energy program and meet its objectives, the Air Force must continue to increase the efficiency of energy use, exploit the use of alternative sources of energy and implement advanced energy technology where possible.

This section has provided an overview of the U.S. Air Force energy policies and goals. The final section of this chapter is concerned with the energy policy of the Air Force Logistics Command.

Air Force Logistics Command (AFLC) Energy Policy

As a result of the guidance provided in Air Force Regulation 18-1 and the USAF Energy Plan, AFLC has developed an Energy Master Plan. The AFLC master plan serves as the basic guidance document for energy management throughout the command. Its stated purpose is to disseminate planning guidance and information to headquarters staff and field elements on energy-related activities and plans throughout the command (2:5).

The energy program at HQ AFLC was first organized in March 1978 with the establishment of the Planning Programming Review Board (PPRB) Energy Panel (see Figure 8).

> This Panel was established to assist the PPRB in performing its functions as the HQ AFLC Energy Conservation Work Group whose establishment was directed by AFR 18-1, 9 January 1979. The primary functions outlined in AFR 18-1 are [2:40]:

1. Developing and assessing monthly energy conservation results.

2. Inspecting or reviewing conservation actions taken by responsible activities.

3. Reporting adequacy of conservation measures to the Commander or Deputy Chief of Staff.

4. Recommending corrective action to the Commander if conservation measures prove to be inadequate.

5. Setting up a contingency plan for energy shortages.

The AFLC Master Plan also notes that the continuing energy problem will make concentration on opportunities to identify and implement energy conserving activities increasingly important as the pressure to demonstrate the federal government's determination and leadership role in energy conservation becomes more pronounced (2:5).

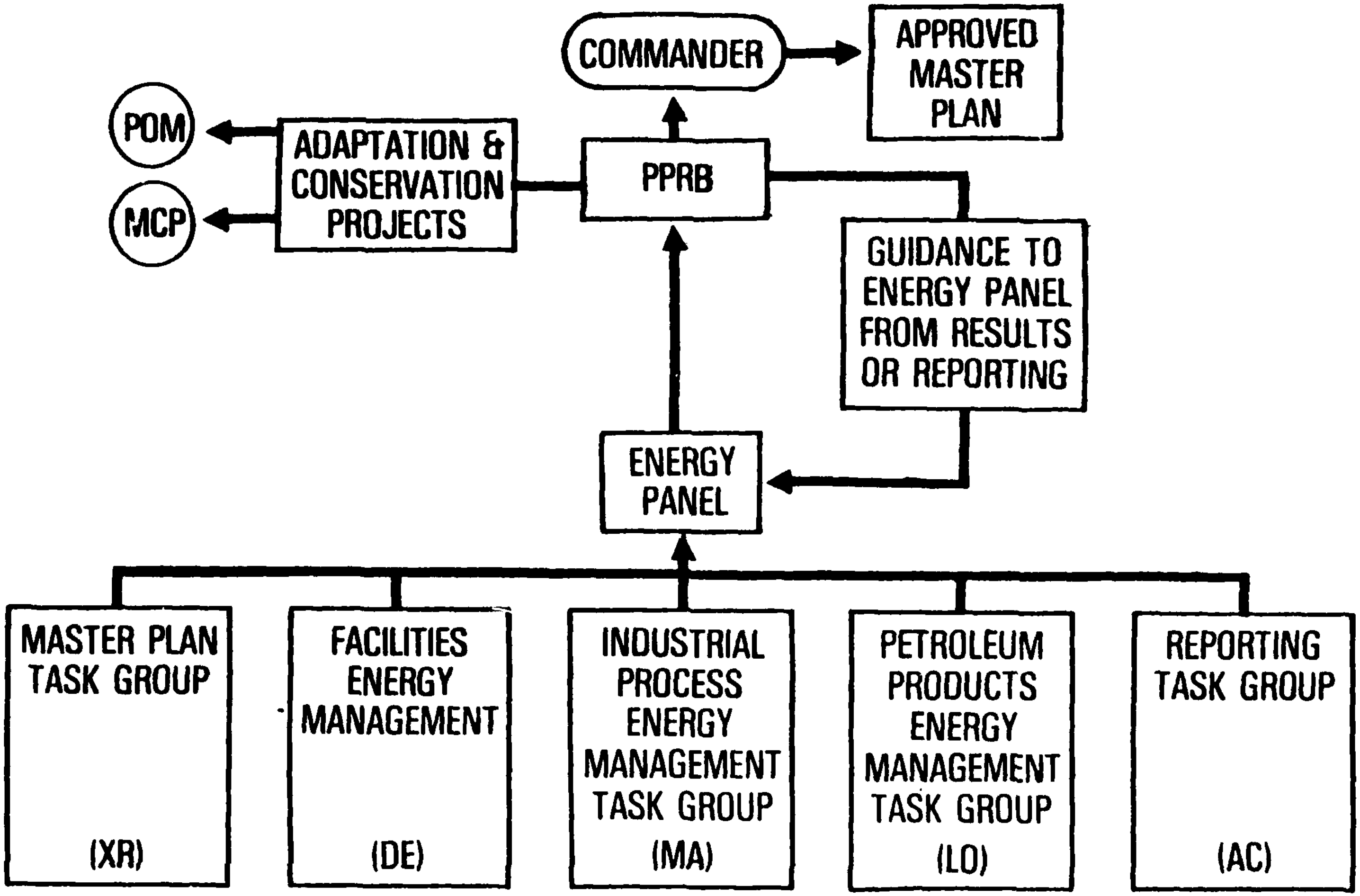

Fig. 8. Command Energy Program [2:45]

It can be expected that DOD will be continually called upon to assume a leadership role in carrying out the national policy of reducing energy consumption. While the federal government uses about 2.2 percent of the total U.S. energy, DOD uses about 80 percent of the federal total.

The Department of the Air Force uses about 45 percent of the DOD total with the majority (69 percent) being used for aircraft operations. Ground transportation uses about 2 percent and the remaining 29 percent is used by facilities and processes (2:5). This information is portrayed in Figure 9. Facility energy consumption by energy type is shown in Figure 10.

Most of AFLC energy is consumed in facilities and processes. It is important that the command be concerned in its efforts of energy conservation because of its close parallel to private industry. As the price of energy increases, opportunities to substitute other resources for energy will mean that increased logistics support effectiveness can be had for a constant price or with minimal increases (2:6).

The basis for AFLC energy objectives centers around planning and programming requirements to accomplish the following (2:8):

1. Reduce energy consumption in existing buildings by 20 percent in FY 1985 as stipulated in Executive

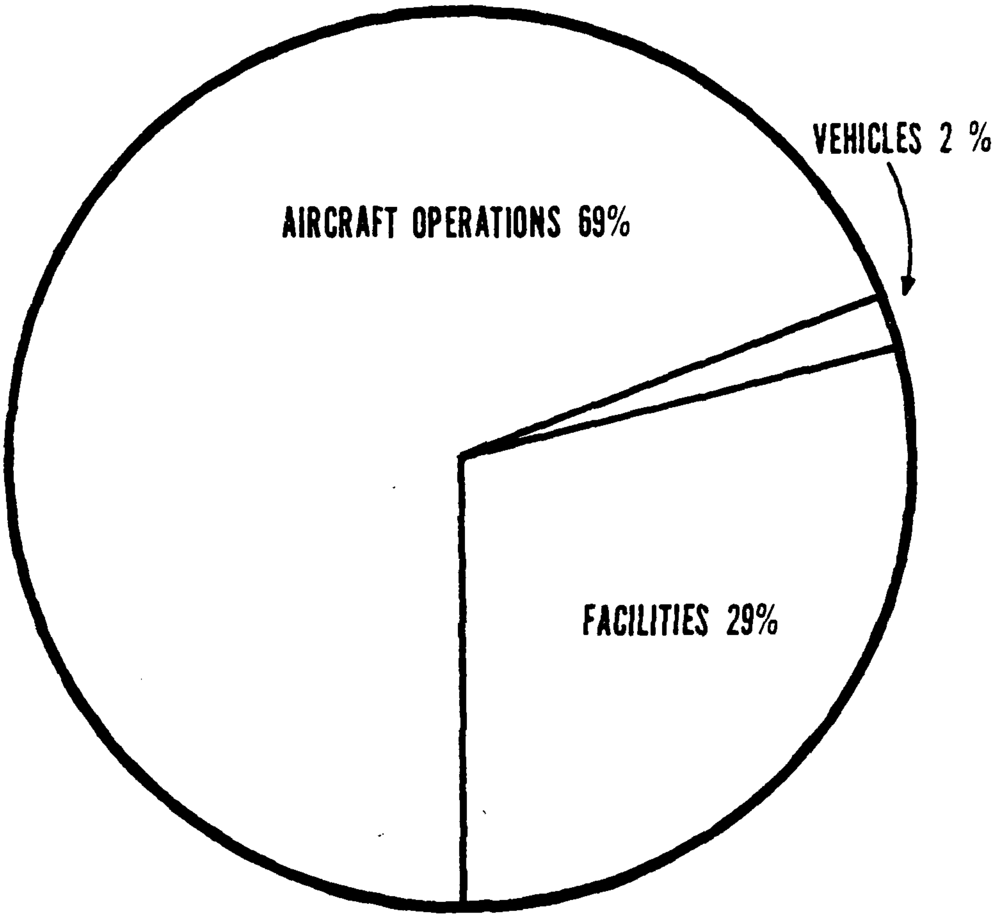

Fig. 9. Air Force Energy Use [95:7]

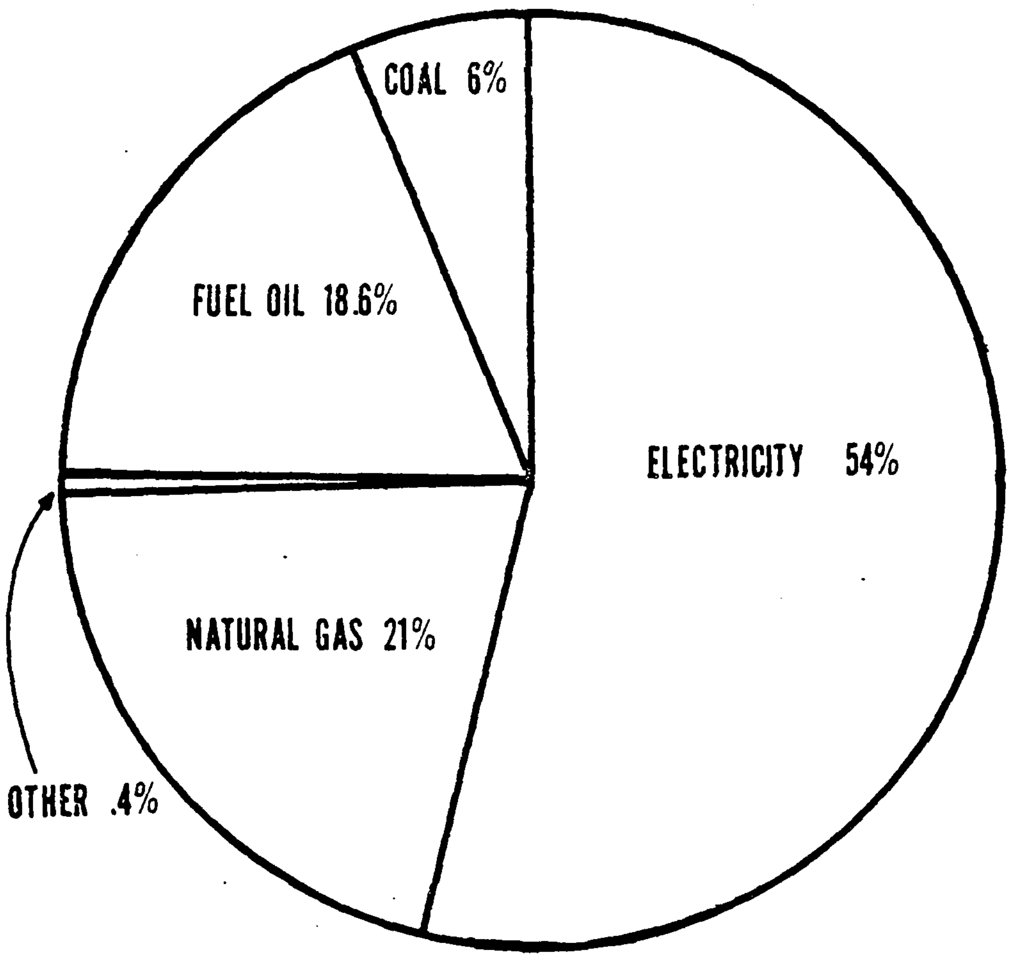

Fig. 10. FY 78 Facility Energy Consumption by Energy Type [95:9]

Order 12003, 20 July 1977. The base line year for energy use in DOD is FY 1975.

2. The average energy requirements per square foot for new buildings will be reduced by an average of 45 percent.

3. Annual goals received by HQ USAF from DOD will be met or exceeded by each field unit.

Planning and programming activities to provide effective control of that portion of expenditures which go to finance energy requirements will center around the following objectives (2:14):

1. The command will achieve self-sufficiency in industrial energy by the year 2000.

2. The command will meet or exceed reductions in energy use stipulated in Executive Order 12003, 20 July 1977.

It was the former objective that we wished to investigate further. Primary emphasis within AFLC was placed on the Air Logistic Centers (ALCs) at Tinker AFB, Oklahoma; Hill AFB, Utah; Kelly AFB, Texas; McClelland AFB, California; and Warner Robins AFB, Georgia. Each base is similar in assigned manpower for industrial funded activities but are located in diverse parts of the United States.[10] Manpower spaces for depot maintenance services and operations

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[10]The mission of the Air Force Logistics Command and each of the ALCs is shown in Appendix C.

and maintenance currently range from a low of approximately 12278 at McClelland to 15025 at Tinker (3).

Although the primary energy source of energy consumed for ALC facilities and processes is in the form of electricity; fuel oil, natural gas, propane, coal and diesel oil are other energy sources which are currently utilized as direct energy sources.

Chapter Summary

Our National Energy Policy has been slow in developing due to many factors which affect the energy system. Although Presidents Nixon and Ford advocated a policy of "Energy Independence," this philosophy has not obtained sufficient backing by our elected officials. While President Carter's proposals will ultimately increase self-reliance on American energy sources, a substantial quantity of our energy requirements will continue to be met by imported oil. As a result, vulnerability as a country and as a military power will continue to be jeopardized.

The Department of Energy views its mission as assuring an orderly transition from scarce petroleum to alternate energy forms. The Department of Defense has established policy in accordance with Executive Orders, the Department of Energy and other national goals and objectives. These policies have been implemented within the various services. The Air Force has developed policy which has been provided to each major command.

One of the primary purposes of our research was to evaluate the AFLC energy goal of providing ALC energy self-sufficiency. The next chapter is devoted to a discussion on the rationale behind pursuing the concept of self-sufficiency.

CHAPTER IV

ENERGY SELF-SUFFICIENCY

A definition of energy self-sufficiency for AFLC Air Logistics Centers is central to this study. Since President Nixon proposed Project Independence in November 1973 calling for national energy self-sufficiency, there has been discussion on a national level as to the direction of ESS and its definition. Additionally, there has been discussion on the need for secure energy sources. In fact, there has been some debate about what is more important and necessary, energy self-sufficiency or rather secure energy sources/resources. Before the results of the research to define energy self-sufficiency for the ALCs is presented in the next chapter, this chapter presents a background on ESS, a rationale for ESS, and some of the debate on the need and appropriateness of national ESS.

Background

It has been said that the energy crisis faced by the United States is actually an oil crisis created by the dependence on the U.S. on imported oil (87:1). There was little national interest in considering the eventual depletion of domestic oil resources as long as energy was abundant and cheap (7:273). This is not to say that no thought whatsoever was given; in the early 1930s many experts believed that the U.S. was facing impending depletion of its crude oil supplies (7:277). The discovery of the huge East Texas oil fields allayed these forecasts. In the early 1950s concern was expressed about the country's potential energy problems. In 1951 President Truman established the President's Materials Policy Commission to examine the adequacy of the nation's resources. This included energy resources as well as other materials and resources considered essential to the overall security of the United States. The report, known as the Paley Report, indicated that energy supply shortages could develop in the future. The commission reported in part: "The gravest problem is the threat to the wartime security of the free world implicit in the pattern of world oil supply that is taking shape [98:2]." The Paley Report also discussed the increasing dependence on Middle Eastern oil. Another author, writing in early 1950, stated his conclusion that:

> The fact remains, however, that the Middle East is today potentially the greatest single source of petroleum in the world. It is an area in which America has and will continue to have a vital interest--an interest that will be economic as well as military [49:5].

The Arab Oil Embargo of 1973 demonstrated that these thoughts were generally all too accurate. While this is not to say the United States was totally unprepared, little national policy preparations were made. The Defense

Production Act of 1950 allows the DOD to be designated as a priority user of materials necessary to meet national defense needs (111:8),[11] including energy resources. While defense needs were planned for, the contingency was for a wartime scenario. The embargo, however, was economic, and has sent into motion an economic "shock" that continues to affect the entire world. The response of the United States was President Nixon's call for Project Independence, making independence from foreign energy sources a stated national goal.

Rationale for Energy Self-sufficiency

The concept of national energy self-sufficiency is one that also requires definition if some means are to be

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[11]The Act allows the President to allocate national resources if he "finds (1) that such material is scarce and critical material essential to the national defense, and (2) that the requirements of the national defense for such material cannot otherwise be met without creating a significant dislocation of the normal distribution of such materials in the civilian market to such a degree as to create appreciable hardship [112:159-160]." He may "by rule or order, require the allocation of" domestic energy supplies if "such supplies are scarce, critical, and essential," and "cannot be reasonably accomplished without exercising the authority specified in" the Act (100:2190-2191). Executive Order No. 10161 delegated the functions of energy allocation to the Secretary of the Interior (101:315). It was to the Secretary of the Interior that the DOD petitioned to invoke the act in 1973 and was subsequently so done. Additionally, the Act provided for much more than allowing the DOD to be designated a priority user of essential war materials and resources. The Act's additional purpose was to stimulate production capacity, particularly of strategic and critical materials. The Act provided for government loans and incentives to this end [9:35-120).

developed to attain it. Furthermore, there would be some rationale for even attempting ESS.

Some Definitions of ESS

Energy self-sufficiency may mean:

> . . . actual and exclusive reliance on domestic resources, the potential to rely indefinitely on domestic resources after some transition period, or the capacity to rely exclusively on domestic resources for only a limited period of time [116:88].

Additionally, energy self-sufficiency may mean that only certain segments of the nation, e.g., domestic dwellings or vital industries, or geographic regions, would be self-sufficient, either totally or limited. ESS may then possibly be a relative condition.

Whatever definition is chosen, decisions must be made based on the country's resource base, including facilities, managerial capabilities, and financing, and its energy consumption requirements (116:189-191).

While the national ESS strategy has not been defined, the general consensus seems to be somewhere less than total self-sufficiency (27:2-3). Energy security and protection against supply interrruptions seems to be the major thought (116:304-307; 13:93-99). In 1975 the DOD stated:

> While it may be that complete national energy self-sufficiency is unnecessary, the degree of our sufficiency must be that any potential supply denial will be sustainable for an extended period without depredation of military readiness or operations, and without significant impact on industrial output or the welfare of the populace [34:245].

ESS for National Defense/ Security Rationale

Industrial power is prerequisite to both military and political power, and modern industrial power is derived in large part from energy, large quantities of energy (9:2). Energy is a key to the national economy. Additionally, the defense capacity of nations has from earliest times been influenced by the prevailing economic system. A nation's economic potential and its ability to mobilize its economy and divert whatever portion of its economy's output necessary to its national defense effort many times determined the nation's survival (17:1-11). This has held true until the present age when a

> . . . nation is likely to derive military advantage from its economic strength only insofar as the strength has been marshalled and brought to bear <u>before</u> the outbreak of actual armed hostilities [17:11].

In other words, a strong economy, with a strong defense sector is important. The time to mobilize a nation's economy for defense is past. Furthermore, the presence of a strong national economy and defense sector may be an effective deterrent to potential aggression.

The United States has recognized that a strong defense sector of the economy is important to the national defense. The nation must be capable of fighting a war at the outbreak of hostilities rather than waiting to mobilize the economy as was done in the two World Wars. Moreover, based on the international political situation that has existed since the end of the Second World War, the economy and society must function in a peacetime fashion as well as a war-prepared one. James R. Schlesinger, a former Secretary of Defense and of Energy said,

> Perhaps the most significant element of the energy crisis, as it has unfolded since the early 70's, is that it provides a new dimension to the political and ideological competition between the United States and the Soviet Union. . . This larger dimension places in proper perspective such matters as fuel shortages and economic performance--for it has the power to determine the political destiny of mankind [83:709].

And as one DOD official stated,

> . . . security is rooted in more than tanks, planes, and missiles. It depends, in the final analysis, on the functioning of the economy and society of the United States [62:3].

As mentioned earlier, the U.S. economy is energy-intensive, requiring the energy from fossil fuels,[12] particularly oil and natural gas; and foreign sources account for approximately 40 percent of this oil. This makes the economy vulnerable to disruptions in foreign supplies. Secretary of Defense Harold Brown expressed similar concern in saying,

> That awareness [of a critical dependence on imported oil] gives added credence to the potential for political, economic or military pressures on us by those who have, or are perceived to have, the ability to halt or at least substantially reduce the global distribution of oil [18:4].

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[12] It is sometimes overlooked that about 10 percent of the coal, oil and natural gas consumed in the U.S. are for non-energy purposes. These include metallurgical, petrochemical, drug, fertilizers, etc. (7:281).

If disruptions were to occur for extended periods, the nation's economic capabilities could be significantly reduced, as could our defense capabilities.[13] The point to be made is:

> Nations have learned that the threat to their security is no longer confined solely to the prospect of armed attack from the outside, but can very well take a less obvious and more subtle form. They have become equally concerned over the non-military threats to their social, economic, and cultural systems--threats such as subversion, espionage, sabotage, and even economic boycott [23:1].

The ability of an adversary to effectively cut the U.S.'s sources of foreign oil could, in effect, lay seige to the country. Considering the distances most U.S. oil imports must travel and the distances of the oil fields, such interruptions are not inconceivably difficult (55:53-54; 49:5; 91:13-14). Of course, this applies also to the U.S. allies, many of whom rely on imported oil to a greater degree than the United States.

> The United States imports more than 20 percent of its energy requirements. Western Europe imports more than 50 percent and Japan more than 90 percent. The United States may turn out to be more vulnerable to pressure exerted directly on its allies than to pressures exerted directly on this nation [82:7].

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[13]The 1973 oil embargo did affect the DOD. The Congressional Research Service reported in its 1974 document, Oil Shortages and the U.S. Armed Services, that the embargo deprived the DOD of about 40 percent of its petroleum supplies, forcing almost total reliance on domestic production (74:45). Operational training and exercises were also curtailed (111:9).

Such pressure on U.S. allies has serious implications for the Total Force Concept[14] of allied defense. Not only do increasing energy costs divert allied spending from defense to energy (68:17-18), it can have a divisive influence on U.S. relations with its allies and friends regarding questions of national policy.

Views on National ESS

As discussed in Chapter II, achieving energy self-sufficiency has been found to be inordinately expensive and, at least for the present, is being delayed. The concept has even undergone some changes from President Nixon's first introduction of the notion. President Ford stated in September of 1974,

> . . . no nation has or can have within its borders everything necessary for a full and rich life for all its people. Independence cannot mean isolation.
>
> The aim of Project Independence is not to set the United States apart from the rest of the world; it is to enable the United States to do its part more effectively in the world's effort to provide more energy [27:2].

The Project Independence Report, made public in November 1974, "defined self-sufficiency in terms of independence from insecure sources of foreign oil, rather than total reliance on domestic supplies [27:2]." (A point that

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[14]The Total Force Concept "means the integration of all Free World resources to provide security for all [8:145]." This includes allied and friendly countries increasing their regional and self-defense efforts and assuming a more proportionate share of Western defense costs.

can be made is that even the total elimination of imported energy or increased reliance on domestic energy sources will not necessarily eliminate disruptions. Such a move will transfer additional power to domestic energy companies, the transportation sector, utilities, and related labor unions. These factors may be easier controlled or influenced than foreign governments but they may not constitute completely secure or controllable energy sources. The United Mine Workers strike of 1977-78 against the coal mining industry is but one example.)

Others have argued that while the cost of achieving energy self-sufficiency may be quite high for the United States, the economic impact on other energy importing nations may be costlier (13:42). Others believe that U.S. energy independence will strengthen international security (116:314). The general consensus seems to be some type of hybrid policy that would free the U.S. to pursue its national policy and continue to guarantee the security of its allies and friends.

This concept of ESS may be better called "self-reliance."

> "Self-reliance" is perhaps a more appropriate concept than "energy independence;" it connotes confidence in our abilities, while "independence" indicates freedom from external influence and control. "Self-reliance" is more positive, has fewer political or nationalistic connotations and reflects a process that encompasses varying degrees of achievement rather than the fixed objective that is implied by "independence."

> Any substantial self-reliance would enable the United States to be relatively invulnerable to foreign energy producers or to any modest import of energy [82:8].[15]

ESS for AFLC Rationale

Aside from the defense rationale, there may be some sound economic reasons for an AFLC energy self-sufficiency strategy. While the Defense Production Act of 1950, and the Emergency Petroleum Act of 1973 provide for the Armed Forces as priority user, the military has come under mandatory directives such as Executive Order 12003 to reduce energy consumption. As should be expected, all segments of the nation are required to share any burden. A question arises, "at what point does conservation affect mission capabilities?" If an extended disruption were to occur, how much of the reduction would or should AFLC bear?

There is increasing concern about the equity of the burden of high energy costs and conservation (57:145-148; 110:13-21; 82:7). Federal legislation has been introduced to encourage, through financial aid, citizen participation in national energy planning (59:214). Extended energy disruptions may require further conservation and division

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[15] Canada has chosen the road of self-reliance. The Canadian government policy is "measured by the degree to which Canada is independent of imported oil from insecure sources, with a Specific Target: To reduce our net dependence on imported oil by 1985 to one third of our total demands [48:2]." This goal may not, however, be reached by even 1990 (20:38-39).

of energy resources among users, regardless of current legislation on the books.

The continuing climb in energy costs has an affect on the division of financial resources. As more funds must go to pay energy costs, fewer are available for other expenses. Additionally, energy costs are generally overhead expenses which must be paid first or "off the top." Energy costs are not seen to stabilize or recede in the foreseeable future. At some point, essential activities may be curtailed not because of insufficient energy supplies but due to increasing costs. As the processes performed by AFLC are not "front line" defense operations, AFLC would seem a likely candidate for cutbacks in energy supplies. However, if this were to occur there could be long-term degradation to the "front line" forces. It could come to a "save now-pay later" situation.

Based on increasing energy costs, reduced money available, and the chance for "easy reductions" in AFLC operations to meet short-term goals in favor of more critical requirements, energy self-sufficiency may be an appropriate strategy to pursue. It is, of course, possible that ESS in the most literal sense could be more expensive. This becomes a question of policy and a definition of the strategy.

Self-sufficiency Precedents

The idea of self-sufficiency is not a new one to the military. Limited self-sufficiency has been part of U.S. military planning for some time. Units are required to keep certain levels of fuels, equipment and supplies as War Reserve Material (WRM) to allow for self-sustained operations for a planned period of time.

The idea of base energy self-sufficiency is not an unique objective to AFLC. The United States Navy has set as one of its objectives the achievement of energy self-sufficiency for its shore facilities several years ago.

> The energy self-sufficiency strategy is directed toward achieving a lesser dependence on petroleum as an energy source for naval forces, thus reducing the mission impact of short falls in imported energy supplies. This involves the selection of local sources singly or in combination to reduce our energy needs at shore facilities [7:32].

The Navy's self-sufficiency efforts also include using renewable energy sources such as solar, geothermal, biomass, and replacing oil and natural gas with more abundant fuels, such as coal (97:32).

As mentioned earlier AFLC has not yet developed an operational definition for energy self-sufficiency. The national considerations and the Navy example may offer a starting point. The next chapter presents the research done to determine a definition for AFLC ESS.

Chapter Summary

This chapter has briefly discussed the background of concern for our energy problem from a national security/ defense point of view. Rationales were given for national self-sufficiency and AFLC ESS. Some implications of energy independence were presented. National considerations and the Navy example may offer some assistance in developing an AFLC ESS definition.

CHAPTER V

RESEARCH QUESTION NUMBER 1: WHAT IS A WORKING DEFINITION OF ENERGY SELF-SUFFICIENCY FOR AFLC/ALCs?

Introduction

Since an operational definition of energy self-sufficiency within the Air Force Logistics Command had not been developed, a major focus of this thesis was to develop such a definition. It was realized that without an operational definition of ESS, the study of the topic, or the implementation of such a program was not possible. This chapter discusses the methodology used to obtain the definition, assumptions made, and the major findings in addition to the definition developed.

Methodology

To obtain an operational definition, the direct questioning method was used. Since the concept of self-sufficiency had originated with the AFLC Commander, we were particularly interested in obtaining his responses. Additionally, since the concept had been espoused for over a year and a half, we were interested in how it had been interpreted by the various key managers whose job it was to manage the energy program and interpret the applicable directives concerning energy policy. Preliminary investigation had revealed a wide range of opinions regarding ESS and we wished to determine the degree of understanding or opinions which prevailed.

The population for our questioning consisted of those individuals who were responsible for interpreting, implementing, or otherwise managing the AFLC energy program. The population included the AFLC Commander, members of the PPRB, ALC Commanders, ALC energy monitors, individuals in the DCS Engineering and Services and other organizations who had an impact on the AFLC Energy program.

A judgement sample was taken from the population for our questioning. Although several attempts were made to talk with the AFLC Commander, his extremely busy schedule precluded this. For this reason, we interviewed the AFLC Vice Commander. The sample also included a representative from each organization making up the AFLC energy panel, each of the ALC energy monitors and a number of personnel on the PPRB. Also various individuals in the DCS Engineering and Services and DCS Plans and Programs were interviewed because of their expertise and impact on the AFLC energy program.

We used an unstructured, "limited free response" (43:533-543) or "open-ended" personal interview technique. This technique was chosen because it provided for "free" discussion of the topic of which little had been previously determined. Open-ended questions give the respondent considerable latitude in phrasing a reply (39:223).

An unstructured limited free response is one in which questions are asked without the intent of eliciting a specific response. Questions are, however, provided as guidelines for the respondent (43:535). The interviews conducted in our study were accomplished by both person-to-person interviews and also by the use of the telephone. Ideally, all interviews would have been conducted on a person-to-person basis; however, because of travel constraints and cost, the individuals sampled at the ALCs were interviewed by telephone. All individuals interviewed at Wright-Patterson AFB were interviewed in a person-to-person setting. There were no reasons to suspect that any significant systematic bias was introduced by using the different data collection techniques.

The interview technique belongs to a class of methods which provides subjective data--"that is, direct descriptions of the world of experience [52:15]." For each interview conducted, responses were recorded separately by both members of the thesis team. The results were then compared and any disagreements were resolved.

We made the assumption that responses would range over varying degrees of self-sufficiency. Responses did in fact range from owning, controlling, and producing all energy requirements for an infinite period of time to providing for some limited energy requirement for a short period of time.

While the ultimate degree of energy self-sufficiency pursued by AFLC will depend on the Commander's decisions, our analysis in this thesis focused on forming a working definition by taking a consensus from among the energy managers and then comparing this consensus with the intended policy of the AFLC Commander.

We made the assumption that respondents would express their actual opinions, but we recognized that since we asked questions about a policy proposed by the Commander, that some respondents might not answer as they truly thought for fear of expressing opposing views. In order to control for this possibility we utilized the doctrine of non-attribution. We recognized that this would reduce the verifiability of responses; however, it was believed that a more accurate definition would possibly result. A total of sixteen Air Force officers and civilians were interviewed in addition to Lieutenant General Richard E. Merkling, the AFLC Vice Commander.

An interview guide was used to serve as a reminder of the areas to be covered. The interview guide was developed after numerous unstructured interviews with personnel knowledgable of the AFLC energy program. The specific questions developed for the interview guide were the result of topics which often arose when discussing the concept of ESS. While all variables affecting the ESS model were not addressed, the ones considered most important by the sample are discussed. A copy of the guide is provided in Appendix D. The guide included the following questions:

1. Do you think energy self-sufficiency is a reasonable and attainable goal by 2000 AD?

   a. (If yes) What do you think is a realistic definition of energy self-sufficiency for AFLC?

   b. (If no) Why not?

2. What scope of energy self-sufficiency do you believe should be attempted?

3. What time period of energy self-sufficiency do you believe should be attempted?

4. What extent of energy self-sufficiency do you believe AFLC should attempt?

5. What methods or techniques should AFLC use to obtain energy self-sufficiency?

6. Do you think that AFLC should concentrate on energy self-sufficiency or, rather, more energy efficient facilities and processes?

7. Would you favor a Defense Utility to provide the energy requirements for DOD facilities and installations rather than individual base self-sufficiency?

Responses listed beneath each question on the interview guides were listed only for ease of recording responses and were not considered all-inclusive and were not specifically asked.

Before discussing the various responses received, some knowledge of what constitutes ALC industrial facilities and processes is necessary. Some examples considered by the respondents and included in the AFLC Energy Master Plan were the following (2:51-197):

1. Foundry shops
2. Heated process tanks
3. Solvent plants
4. Welding shops
5. Paint shops
6. Equipment test stands
7. Heat treating facilities
8. Cleaning tanks
9. Plating shops
10. Process air moisture removers
11. Refrigerated filter/dryers
12. Plastic curing process
13. Grinding process
14. Propellant test facility
15. Air Compressing facility
16. Conveyors
17. Jet engine test cells

18. Plexiglass shops

19. Machining processes

20. Corrosion control facilities

The next section provides an analysis of comments received by the respondents.

Discussion

Of the sixteen respondents sampled, some did not answer all of the questions posed to them. In some instances the respondent would avoid or talk around the question being asked. For this reason the results obtained from the interviews can be interpreted differently. Table 4 provides summary information based upon the number of respondents who actually stated an opinion. Table 5 provides summary information for all personnel sampled including those who did not respond to the question. Questions 1, 3, 4, 6, and 7 included individuals who would not respond to questions. Only in question number 7 which had five non-respondents, were the summary percentages appreciably changed. For this reason, it is difficult to make conclusive remarks as to the findings for that one question. Discussion of the responses for each question is based upon Table 4 with the exception of question 7.

It should be noted that question 5 permitted more than one answer and many respondents had multiple responses. For this reason, a total of sixty-three responses was recorded and summary data were based upon

TABLE 4

INTERVIEW GUIDE ANALYSIS

Question	Answer		Number	Percentage
1	Yes		5	33.3
	No		5	33.3
	Depends		5	33.3
		Total	15	99.9
2	No		0	0.0
	Own		6	37.5
	Stockpile		9	56.3
	Vertical		1	6.3
	Horizontal		0	0.0
		Total	16	100.1
3	Indefinite		3	20.0
	1 year		1	6.7
	6-12 months		1	6.7
	3-6 months		1	6.7
	30-60 days		8	53.3
	Do not know		1	6.7
		Total	15	100.1
4	Total		2	13.3
	All industrial		4	26.7
	Priority		3	20.0
	Minimum		5	33.3
	Do not know		1	6.7
		Total	15	100.0
5	Cogeneration		8	12.7
	Solar		8	12.7
	Geothermal		4	6.3
	Biomass		4	6.3
	RDF		6	9.5
	Coal		9	14.3
	Nuclear		7	11.1
	Total energy		5	7.9
	Photovoltaics		5	7.9
	Waste		7	11.0
		Total	63	99.8

TABLE 4--Continued

Question	Answer		Number	Percentage
6	ESS		0	0.0
	Energy efficiency		6	42.9
	Both		8	57.1
		Total	14	100.0
7	Yes		5	45.5
	No		5	45.5
	Maybe		1	9.1
		Total	11	100.1

TABLE 5

INTERVIEW GUIDE ANALYSIS--ADJUSTED

Question	Answer		Number	Percentage
1	Yes		5	31.2
	No		5	31.2
	Depends		5	31.2
	No Response		1	6.3
		Total	16	99.9
3	Indefinite		3	18.7
	1 year		1	6.3
	6-12 months		1	6.3
	30-60 days		8	50.0
	Do not know		1	6.3
	No Response		1	6.3
		Total	16	100.2
4	Total		2	12.5
	All Industrial		4	25.0
	Priority		3	18.7
	Minimum		5	31.2
	Do not know		1	6.3
	No Response		1	6.3
		Total	16	100.0
6	ESS		0	0.0
	Energy efficiency		6	37.5
	Both		8	50.0
	No Response		2	12.5
		Total	16	100.0
7	Yes		5	31.2
	No		5	31.2
	Maybe		1	6.3
	No Response		5	31.2
		Total	16	99.9

this total. Also, comments by General Merkling are not included in the following analysis but are addressed separately.

Question Number 1

As Table 4 indicates, only 33.3 percent of the respondents actually though that energy self-sufficiency was attainable by the year 2000. The other respondents thought that goal was either not attainable or that it depended upon the definition of ESS.

A typical definition of those individuals that thought ESS was possible was that energy should be available for a finite period of time (usually thirty days) for minimum essential needs. One respondent believed that ESS should not be defined too closely because it may curtail creative thinking and exclude ideas that would help attain ESS.

Most respondents were not sure how to attain ESS. Many felt that ESS by the year 2000 was "a dream" because of time and money constraints; however, they all believed that the ALCs should attempt to become as self-sufficient as possible.

A few members of the sample believed that it would be "economic folly" if each base were to become ESS. They expressed support for a policy of national ESS. Some energy managers sampled thought that it was imperative that the country continue to develop nuclear energy to reduce dependence on foreign oil.

Many respondents expressed a desire to have a clear definition of what ESS was. They believed that in order to plan for ESS, they should know what to plan for.

Question Number 2

With regard to the desired scope of ESS, the majority of respondents believed that Air Logistic Centers should stockpile resources such as coal to provide for electrical or heat generation. Approximately 37 percent thought that the ALCs should own their own generating plants for all forms of energy. Only one respondent indicated that ALCs should own both the energy producing facilities and also the source of supply for the facility.

Question Number 3

The majority of all managers sampled believed that the time period to be attempted for ESS should be in the range of thirty to sixty days. Most respondents indicated that much would be determined by the scenario that would be considered and the resulting mission requirements. Most respondents believed that the type of fuel to be stored would be a limiting factor to be concerned with. Of the respondents who advocated ESS for at least one year or indefinitely, no one was able to provide a method of insuring uninterrupted energy supplies.

Question Number 4

Over 33 percent of the respondents believed that the extent of energy self-sufficiency should be developed upon some minimum based on war time or emergency essential conditions. Twenty percent of the respondents advocated that the extent should be based on a priority system. Twenty-three percent thought that all industrial facilities should have ESS. Only two of the individuals sampled thought that the extent should include all base functions.

Comments which were typical included the belief that the extent should be as much as possible depending on the operations plans. Most thought that it would be necessary to eliminate "nice to have" energy consumption during periods of shortages. Administrative support and comfort uses were included in the "nice to have" category. Many recommended saving petroleum products for weapon systems and transportation.

Question Number 5

Almost all energy managers believed that the techniques or methods to be used by AFLC to gain some degree of ESS should include a wide variety of options. No respondent advocated the use of just one energy source such as coal or nuclear. It was recognized that coal may be a "quick and easy" solution; however, it is often expensive and environmentally undesirable. When cogeneration and total energy systems were advocated, they were usually discussed in conjunction with the use of coal as the energy source.

Most managers noted that the energy techniques used should be designed to suit the individual installation and that no one option was suitable for all ALCs. Although a wide range of technologies was advocated, the majority of respondents advocated the greater use of solar or energy derived from waste products.

Question Number 6

When asked whether AFLC should concentrate on energy self-sufficiency or rather on more energy-efficient facilities and processes, the majority of respondents believed that both should be attempted at the same time. Several respondents noted that the two objectives went "hand-in-hand" because of the current Administration's executive order to increase energy efficiency, and ESS could not be achieved without increased efficiency.

Many respondents believed that the two options should be compared from an economic standpoint to determine the best one to pursue. Several managers noted that conservation still had much to contribute to reducing the overall requirements for energy.

Question Number 7

Respondents were evenly divided on the concept of a Defense Utility providing energy requirements for DOD facilities and installations rather than individual base self-sufficiency. Most managers, however, recognized that this concept would be applicable only in certain areas such as those having a high concentration of DOD or federal facilities.

Most respondents thought that the Defense Utility concept would be rebuffed by the local utility companies now serving the bases. It was also believed that the concept would be cost prohibitive.

Interview with Lt. General Merkling

On 9 May 1980 we had the opportunity to conduct a personal interview with Lt. General Richard E. Merkling, the AFLC Vice Commander. The purpose of the interview was to obtain the Command's interpretation of the concept of ESS for the ALCs' industrial facilities and processes.

General Merkling noted that he had not discussed this specific subject with General Poe. He did, however, have his own opinions as to what ESS meant and he thought that these ideas were similar to General Poe's (64).

General Merkling believed that ESS for the ALCs meant that the depots would have the capability of producing their own energy for a thirty to sixty-day period and that the base would "not have to move energy sources, raw or otherwise, across the field boundaries of the depot [64]." This would mean that the depot could lose commercial electrical power and could still operate the industrial facilities and processes.

He emphasized that this would involve severely constraining the depot operation. A very austere program would be implemented that would allow the industrial processes to continue but there would be significant changes in the creature comforts.

As far as the methods to accomplish this objective, the General noted that supplies of coal, RDF or waste materials could possibly be built up over a long period of time to accomplish the goal or that the ALCs would have sufficient quantities of used solvents or other by-products used in the industrial processes that could be utilized to generate power in the thirty to sixty-day surge period.

The General noted that in the past the Command ". . . looked at energy in ways that were not as effective as they could be [64]." He touched on the concept of steam versus electrical lead for power plants and noted that the command needed to determine what it really needed for each ALC. He mentioned other new technologies that are also gaining popularity such as new turbines and atomizing techniques of combustion. He noted that some of the new technologies may produce substantially more power than the depot would require.

The General commented that the time had probably come whereby federal installations needed to be a partner with the local communities and public utilities and that the utilities should be encouraged to take any excess electrical capacity that a depot may have. He realized this concept would require some changes in laws; however, he had discussed the idea with several congressmen and they seemed very receptive to the idea (64).

The General advocated the consideration of a wide range of alternate energy sources such as solar, geothermal, waste products and other technologies to help attain ESS. He noted that the technologies would probably have regional applications, especially solar and geothermal; however, he did not rule out any technique and solicited our opinions on the matter. He expressed the desire that further research be done into the various energy options as to their potential contribution to the ALCs (64).

General Merkling noted that changes in processes may be necessary to utilize the new technologies that may be used. He made mention of the concept of using solar power in conjunction with a "pulse" plating process whereby solar could provide the electrical pulse power for the plating (64).

Chapter Summary

As evidenced by the various responses offered by the individuals interviewed in the sample, a wide range of opinions existed concerning the concept of ESS for ALC industrial facilities and processes. However, the most prevalent responses recorded did not differ too greatly from the interpretation given by General Merkling.

The overall definition for AFLC ESS appears to be the following: The ALCs should have the capability of producing their own energy for a thirty to sixty-day period by utilizing stockpiled resources such as coal, RDF, or waste or through the use of energy sources such as solar that do not require stockpiled reserves. This requirement would be based upon the needs of the industrial facilities and processes and on an austere level for all other depot activities. The depots should utilize the most applicable energy technologies available to them considering regional as well as demand and other requirements. In conjunction with ESS, energy efficiencies should be exploited to reduce energy consumption. Changes in current industrial processes may be necessary to accomplish this.

The next chapter presents an analysis of aggregate ALC energy consumption and some variables which may effect the consumption. A statistical model is presented for predicting future energy requirements.

CHAPTER VI

RESEARCH QUESTION 2: WHAT IS A FORECASTING MODEL FOR AGGREGATE ALC ENERGY CONSUMPTION?

Introduction

As mentioned in Chapter I, a principal requirement for achieving energy self-sufficiency, based on its definition, is a determination of the level of energy consumption that must be planned for to achieve energy self-sufficiency. Without some knowledge of the amount of energy that is required by AFLC Air Logistics Centers, the facilities and technologies to provide ESS cannot be properly planned. The ability to forecast or estimate energy requirements is essential (72:22).

> In fact, energy forecasting is a crucial step in the policy process for any aspect of energy use that requires substantial "lead times" for development or involves physical limits imposed by resource availability [6:93].

Based on the systems concept that "the whole is greater than the sum of the parts," a forecasting model was developed to estimate aggregate ALC energy consumption.[16]

[16] This type of forecast may also offer some insight into the determinants of energy consumption at the individual ALCs. This may be valuable when further research is done to determine the best energy alternatives for achieving whatever level of ESS that is desired. Additionally, AFLC energy conservation goals are levied by HQ USAF as a command-wide goal, rather than on individual basis. This type of forecast may offer utility for meeting these aggregate goals.

The systems approach and methodology is considered appropriate for use in developing forecasts (5:9-12) and

> The rationale for this "top-down" view is that the demand for different sources and forms of energy is interrelated because of substitutability among fuels and energy forms . . . [and] total energy demand can be met through many "mixes" of these fuels and forms, with the proportions varying according to the relative price of each type . . . [and] total energy supply is also important per se because of the general effects of energy use [on other factors, e.g., pollution levels] [6:95].

To develop the forecasting model the statistical technique of regression analysis was used. This technique was chosen because it offers a method for determining relationships between two or more variables, provides the ability to easily manipulate variables, and its methodology is well documented. This chapter presents the methodology used to develop the forecasting model or energy estimating relationship (EER), the data base, sampling plan, and the EER itself.

Methodology

Data Description and Acquisition

The dependent variable (Y) in all instances was energy consumption expressed in millions of British thermal units (MBTUs). Monthly energy consumption data were obtained from the AFLC Defense Energy Information System (DEIS) reports which provide MBTUs for every type of energy utilized at each AFLC installation. The data were not checked for accuracy with any other source. However, since the data are utilized for reports submitted to the Air Staff and ultimately to the DOD, it is subjected to great scrutiny for reliability and accuracy. Any questionable data are reviewed by HQ AFLC Engineering and Services personnel prior to forwarding to HQ USAF, and corrections made as necessary. For these reasons, it was believed that the data were accurate and reliable for purposes of our analysis. (The data were, however, physically screened for unusual or seemingly askewed points, and none were found.) Monthly energy consumption for each of the five ALCs (Warner-Robins (WR-ALC), Kelly (SA-ALC), Tinker (OC-ALC), McClelland (SM-ALC), and Hill(OO-ALC), was consolidated for an ALC total. This total included energy expended in the form of electricity, diesel fuel for heating or generating electricity, natural gas, propane, and butane. This energy was expended primarily for facilities and processes. Energy data did not include fuels used by vehicle operations or those utilized by AFLC supported flying missions. These data were obtained from mid 1975 (when DEIS reporting began) to the end of FY 1979 (30 September 1979). The data were collected in November 1979.

The independent variables (X_is) were chosen because of their possible influence on energy consumption. These were: heating and cooling degree days, manmonths worked, square footage of floor space, and capital investment in industrial facilities and processes.

Heating and cooling degree days were obtained because of the affect temperature should have on the use of energy. Degree day data were obtained from the AFLC DEIS report. These data were acquired in the same manner and at the same time as the energy consumption data, and are subject to the same review and validation as the energy data. These data are analyzed by HQ AFLC/DEMU (Utilities Division) prior to developing reports to higher headquarters. Degree days are obtained by observing the mean (average) daily temperature in degrees Fahrenheit (°F) compared with a standard of 65°F. Temperatures above 65°F are considered cooling degree days and temperatures below 65° are considered heating degree days. As with the energy consumption data, these were summated for an ALC total.

Manmonths worked were obtained for two reasons. Several AFLC energy managers believed that employees, their numbers and time worked, may affect energy consumption, and a Massachusetts Institution of Technology study found number of employees significantly related to energy consumption (63:27-28). Manmonth data were obtained from historical records maintained by the HQ AFLC Civilian Personnel Office (3). The data, which were obtained on a monthly basis, reflect manmonths worked at each ALC for total assigned personnel strength. These data reflect not only operations and maintenance manmonths, but also depot maintenance services manmonths. A summated figure for the five ALCs was utilized. These data were obtained for the period, July 1975 to September 1979, which corresponds to the time period of the data obtained from the DEIS report.

Square footage of floor space was chosen as an independent variable. HQ AFLC/DE had been discussing using this factor to report energy conservation goals; also the MIT study found square footage to be significant. These data were obtained from HQ AFLC/DEPR (Requirements Division). The AFLC RCS:HAF PRE 7115 report contains square footage of floor space for all facilities within AFLC. Totals were obtained for each ALC and then summed for an ALC total. Since the 7115 report changes only when new facilities are acquired, or when older ones are disposed of, expanded, or reduced, it is not prepared on a monthly basis. For that reason totals were carried as constant from one month to the next until some change occurred. Again, an ALC total was obtained by summing the square feet for each ALC.

Capital investment was chosen as an independent variable as a possible indicator of equipment and plant influences on energy consumption. Capital investment data on all Real Property Installed Equipment (RPIE) was obtained from each ALC. These data were also acquired from the RCS:HAF PRE 7115 Report and AFLC Real Property Records maintained by HQ AFLC/DEPR. These data represent the dollar investment that AFLC has in facilities at each ALC. Only facilities and RPIE are costed in the report. Facilities and equipment are capitalized and entered into the report after acceptance into the inventory. Like the square footage data, capital investment is not prepared on a monthly basis, so totals were carried from one month to the next until a change occurred. Likewise, an ALC total was obtained by summing the capital investment for each ALC.

The selection of these five independent variables assumes away other potential variables, e.g., age of equipment or its state of repair. However, in order to manage the model these five variables were considered to have significant potential for the initial EER. These data were considered to be ratio level data since each has a defined zero point and the distances between data elements were fixed and of equal units, e.g., MBTUs or manmonths worked. (A summary of the data base is found in Appendix E.)

Sampling Plan

A monthly sampling plan was selected for the following:

1. Energy consumption
2. Manmonths worked
3. Degree days (Heating)
4. Degree days (Cooling)

These data were selected on a monthly basis because the permanent records from which the data were extracted are maintained on a monthly basis and this unit of measurement allows for sufficient data points to perform analysis. The sample included all monthly data from October 1975 to September 1979. This period was selected because it gave a complete four fiscal years of data, which provided a sufficiently large number of observations (48) to determine what, if any, statistical relationships existed between energy consumption and the selected independent variables. The data obtained in this manner constituted a convenience sample.

Because data on square footage of floor space and capital investment were recorded at irregular intervals, they were recorded as continuous monthly totals until some change was made. Generally these data were maintained on a semi-annual basis. However, prior to FY 7T (the fiscal year transition quarter) the data were often reported in different reporting periods (five, six, or nine months). It is for this reason the data were used as continuous for several months (usually six) while the other variables were used on a monthly basis. Once again these data were collected for the period of July 1975 through September 1979 and represent a convenience sample.

For purposes of testing the accuracy of the EER, data were also collected for all variables for the period of August, September 1975 and October 1979 through March 1980. These data were not included in the data base for the development of the model.

Statistical Technology

To develop the forecast model the Statistical Package for the Social Sciences (SPSS) regression subprogram was used. To test the aptness of the model and if there were relationships between the dependent and independent variables other SPSS programs were used and are identified when the test is presented.

Prior to the development of the model it was determined that some minimum correlation coefficient and significance level would be set. The correlation coefficient chosen was determined from a table of correlation coefficients based on a level of significance (80:563; 41:63). The level of significance selected for use throughout the study was .01. This level of significance was selected to be 99 percent certain that the variables in the regression equation were related to energy consumption, and there would be a 99 percent certainty that the applicable tests would be correct. Based on this level of significance the correlation coefficient determined as a minimum required for statistical relationship between variables was .3721, based on the sample size of 48 observations. Additionally, it was decided that the inclusion of a variable in the model should add significantly to it. The SPSS regression subprogram allows, through the stepwise inclusion option, the ability to control the inclusion of variables in a regression equation. This is done by the specifying of a level of significance and selecting the stepwise option. The stepwise option enters one variable at a time into the equation based on its relative contribution to the model with regards to the other variables. This option was selected for use with a significance of .01. Based on these criteria a potential linear regression model, with all variables in the equation, was:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_5 + \beta_5X_5 + e_i$$

where:

Y = Energy consumption

X_1 = Manmonths

X_2 = Square footage of floor space

X_3 = Capital investment

X_4 = Heating degree days

X_5 = Cooling degree days

β_0 = Computed intercept of the regression line

β_is = Coefficients computed for each independent variable

e_i = Random error term

Before continuing with the development of the model it is interesting to note the distribution of the dependent variable and independent variables over time, as well as the independent variables against the dependent variable. These are presented in Appendix F. Against time energy consumption and heating and cooling degree days show definite seasonal fluctuations. Manmonths worked were decreasing over the sample period, and square footage of floor space and capital investment were increasing. Plotted against energy consumption only heating and cooling degree days show any discernible pattern.

When the variables were run through the SPSS regression program using the stepwise regression option and a .01 level of signifiance for entry into the equation, only heating and cooling degree days entered as variables meeting the criteria. This equation took the form of:

$$\hat{Y} = \beta_0 + \beta_4 X_4 + \beta_5 X_5$$

where:

$\hat{Y}$ = Estimated energy consumption for a given month

β_0 = 1051672.3 MBTUs

β_4 = 195.02 MBTUs

β_5 = 79.36 MBTUs

X_4 = Heating degree days for a given month

X_5 = Cooling degree days for a given month

The SPSS run for this equation is presented in Appendix G.

Before determining the accuracy of the EER various tests were run to determine if there were a relation between variables and if the linear model were apt.

To test if there were a regression relation, a one-way analysis of variance (ANOVA) was run. The test hypotheses were:

H_o: $\beta_0 = \beta_4 = \beta_5 = 0$

H_a: Not all β_is = 0

If all beta (β_is) coefficients in the estimated equation were equal to zero, then no regression relation between Y (energy consumption) and the independent variables (heating and cooling degree days) actually existed.

The decision rule was given by:

$F^* \leq F(1-\alpha;p-1;n-p)$, conclude H_o

$F^* > F(1-\alpha;p-1;n-p)$, conclude H_a

where: F* is given by the SPSS output and compared to a F table value with p-1 and n-p degrees of freedom; p=3 (the number of β_is); n=48; α=.01. This test is summarized in Table 6. This table shows that not all β_is equal zero; therefore, a regression relationship between energy consumption and heating and cooling degree days can be assumed.

TABLE 6

ONE WAY ANOVA TABLE

F* = 175.55	p-1(3-1) = 2 degrees of freedom
$1-\alpha(1-.01) = .99$	n-p(48-3) = 45 degrees of freedom
F table value ≅ 5.13	175.35 > 5.13 conclude H_a

To test the individual beta coefficients a test was performed to determine if any of the coefficients could be dropped from the model. The hypotheses were:

$$H_o: \beta_k = 0$$
$$H_a: \beta_k \neq 0; \quad k=4, 5$$

If the test reveals a coefficient is zero then it can be removed from the equation. The decision rule was:

$$|t^*| \leq t(1-\alpha/2;n-p), \text{ conclude } H_o$$
$$|t^*| > t(1-\alpha/2;n-p), \text{ conclude } H_a$$

where: $|t^*|$ is the square root of the F value provided by the SPSS program for each variable in the equation and compared to a Student's t table value with n-p degrees of freedom at the $1-\alpha/2$ significance level. Table 7 summarizes this test. This table shows that the beta coefficients are not zero and can be assumed to add to the model.

To determine if the model was apt residual analysis was performed. If the residuals reflect the properties of: (a) linearity, (b) constant variance, (c) being normally distributed, and (d) statistically independent, then the model could be considered apt.

To test for linearity of the regression model a plot of the residuals against the fitted value (estimated energy consumption) was examined. If the residuals scatter randomly about the zero axis, this suggests the

TABLE 7

TEST OF COEFFICIENTS

β_4 (Heating degree days)	β_5 (Cooling degree days)
$\|t^*\| = \sqrt{198.049} = 14.073$	$\|t^*\| = \sqrt{10.80} = 3.286$
$\alpha = .01 \div .2 = .005$	$\alpha = .01 \div 2 = .005$
$1 - \alpha = .995$	$1 - \alpha = .995$
$n-p = 48-3 = 45$	$n-p = 48-3 = 45$
t table value $\cong$ 2.693	t table value $\cong$ 2.693
14.073 > 2.693, conclude H_a	3.286 > 2.693, conclude H_a

model is linear. Appendix H presents this plot. Additionally, the SPSS nonparametric runs test was performed to test for this randomness. The hypothesis was:

H_o: The residuals are randomly distributed

H_a: The residuals are <u>not</u> randomly distributed

The decision rule was:

SPSS produced probability > α, conclude H_o

SPSS produced probability < α, conclude H_a

The SPSS produced probability was .115 and α was .01, therefore conclude H_o; the residuals are random. This is also suggested by the plot.

An inspection of the residual scatter plot was also used to test for constant variance. As no pattern was evidenced in the plot of the residuals, no departure of constant variance was suggested.

One test for normality available on SPSS is the Kolmogorov-Smirnov (K-S) goodness of fit test. This test was conducted on the residuals and the output is displayed in Appendix H. The hypothesis was:

H_o: The residuals are normally distributed

H_a: The residuals are not normally distributed

The decision rule was:

D > K-S table value, reject H_o

D < K-S table value, accept H_o

where D is the max absolute difference between the sample distribution and the actual (hypothesized) distribution. The test statistic is given by the SPSS output and is displayed in Appendix H. In this instance D was given as .1192 and the K-S table value at the .01 level of significance was .2353; therefore, .1192 < .2353, conclude H_o, the residuals are normally distributed.

The SPSS regression program provides the Durbin-Watson test which can be used to test for independence and serial correlations of residuals. The hypotheses tested were:

H_o: The residuals are independent

H_a: The residuals are <u>not</u> independent

The decision rule was:

$d < d_L$, conclude H_a

$d_L < d < d_U$, undecided

$d > d_U$, conclude h_o

where d is the test statistic and d_L and d_U are table values with p-1 degrees of freedom for a given level of significance; .01 in this case. Table 8 summarizes this test. In this case, the test results suggest that the residuals are independent and not serially correlated. The output is displayed in Appendix H.

TABLE 8

DURBIN-WATSON TEST

d (from SPSS output) = 1.58755
p-1 (3-1) = 2
$d_L = 1.24$; $d_U = 1.49$
1.58755 > 1.49, conclude H_o

Since these tests support the assumptions of the aptness of the model, it was concluded that the linear regression techniques could provide an energy estimation relationship, and this could be used to estimate energy consumption.

To test the accuracy of the model the data which were not used to build the regression equation were used.

These data and the predicted energy consumption are presented in Table 9. The table shows that the EER is fairly accurate in predicting energy consumption. Appendix I presents the errors associated with the data base used to construct the model. With the exception of two periods, March 1978 and 1979, the model predicts well within ± 10 percent. This high error appears to be due to an abnormally high number of heating degree days (at least in March 1978) experienced in that month, followed by a steep drop in heating degree days in the next month.

The difficulty with using this model is that it requires the estimation of heating and cooling degree days in some future month. However, with the rather extensive statistics kept on temperatures in the United States, and the number of techniques available for various kinds of estimating, this should not be exceedingly difficult.

It is interesting to note that none of the other independent variables entered the equation. Appendix J presents the SPSS output when the significance level was not specified in the stepwise inclusion. Of note is that square footage of floor space never enters the equation. This would suggest that there is little relationship between this variable and energy consumption, at least in the presence of the other variables. Additionally, when all variables are "forced" into the equation little

TABLE 9

PREDICTED VERSUS ACTUAL ENERGY CONSUMPTION

EER: $Y = 1051672.3 + 195.02X_4 + 79.36X_5$

Where: Y is estimated energy consumption in a given month in MBTUs
X_4 is heating degree days for a given month
X_5 is cooling degree days for a given month

Date	X_4	X_5	Actual	Predicted	Error	Percent
Aug 1975	12	2015	1,205,792	1,213,923	- 8,131	- .7%
Sep 1975	118	114	1,160,301	1,083,732	76,569	6.6%
Oct 1979	603	554	1,192,048	1,213,238	-21,190	-1.78%
Nov 1979	2386	65	1,455,606	1,522,148	66,542	4.57%
Dec 1979	3068	72	1,583,934	1,655,708	-71,744	-4.5%
Jan 1980	3249	8	1,736,742	1,682,678	50,064	3.11%
Feb 1980	2859	14	1,672,105	1,610,346	61,759	3.69%
Mar 1980	2246	70	1,416,696	1,495,242	-78,546	-5.5%

improvement is made over the heating and cooling degree day model (Appendix J).

This is not to be unexpected, however. The vast majority of ALC energy consumption is generated by industrial processes, which do not necessarily relate to the more traditional thoughts on the "drivers" of energy consumption. Figure 11 shows the comparison of AFLC thermal energy requirements to the other commands. This thermal energy is indicative of the ALC industrial processes.

Based on the MIT study, which found that if energy consumption were normalized by dividing by heating and cooling degree days, some consistent prediction results were obtained with square footage of floor space and population. Based on this finding, the energy consumption for the ALCs was normalized in this manner. Appendix K displays the SPSS output. The output strongly suggests this is not the case with ALC energy consumption. Since the majority of ALC energy is for industrial process, again this is not too surprising.

Several other models were run to determine if a better prediction could be found. The only one worth noting is a log-linear variation of the model presented. Interestingly, the natural logarithms of energy and the reciprocal cooling degree days provided a somewhat more accurate prediction except over the high energy consumption months. This is presented in Appendix L. Since the best

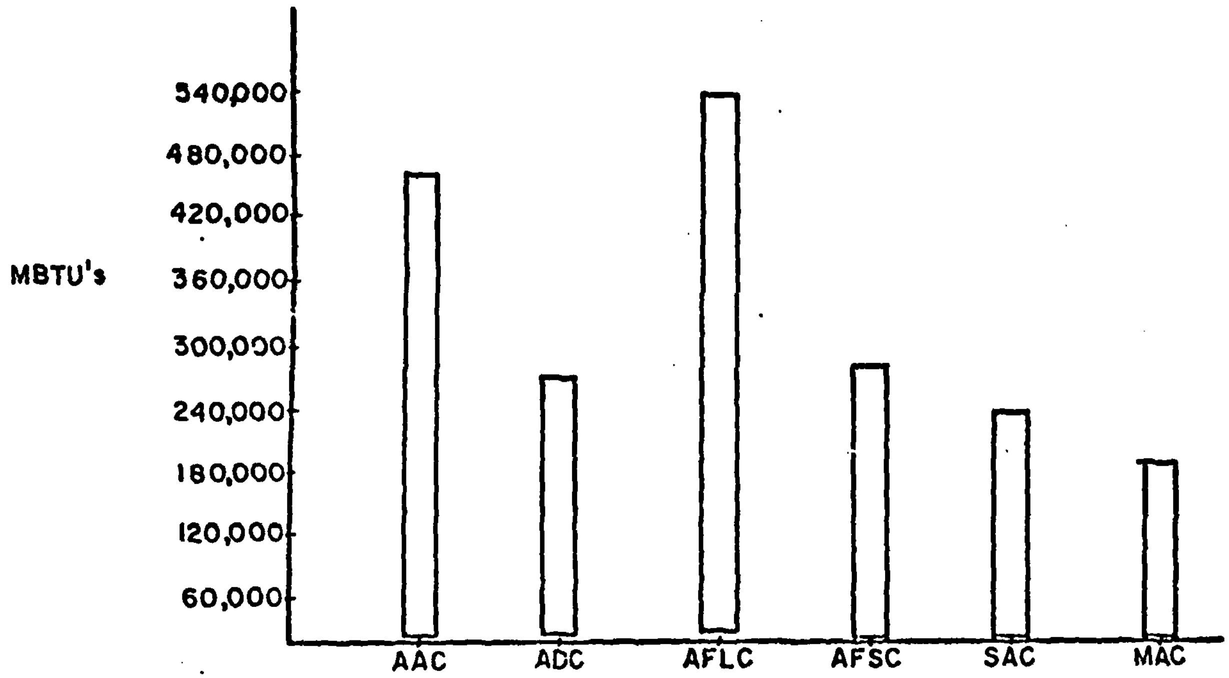

Fig. 11. Air Force Major Commands Monthly Thermal Energy Use (FY 75 Only) (45:7)

overall model was the one described in detail here it is the only one presented.

Chapter Summary

This chapter has presented a statistically derived energy estimating model. It was found that heating and cooling degree days were the most significant determinants of aggregate ALC energy consumption. This finding was not too surprising since the majority of ALC energy usage is for industrial processes rather than comfort heating and cooling Had the latter been the case, square footage of floor space and manmonths worked could possibly have been more significant.

In the next chapter possible unconventional energy sources are presented that may be of use to AFLC in achieving energy self-sufficiency. The chapter emphasizes waste recovery technology and solar applications.

CHAPTER VII

RESEARCH QUESTION NUMBER 3: WHAT ARE POSSIBLE TECHNOLOGIES THAT CAN BE USED TO ACHIEVE ESS FOR AFLC AIR LOGISTICS CENTERS?

Introduction

After considering the responses obtained in research question number 1, we wished to investigate technologies which were advocated by the majority of respondents as having the potential for aiding AFLC in its objective of achieving energy self-sufficiency. Although conventional energy sources were advocated for continued use and even further development (in the case of nuclear and coal) much emphasis by the respondents was placed on the development of smaller and unconventional energy sources. The majority of respondents thought that more ALC energy should be derived from technologies that fell into the basic categories of waste and solar.

It was believed that because these energy managers had significant technical and managerial expertise and were involved in the mainstream of interpreting and implementing AFLC energy policy, they would be in the best position to recommend the energy sources and technologies to be used at the ALCs. Some of the individuals interviewed were in a position in which they would either submit or review programming documents for the construction of new energy related facilities. Other individuals were involved in the review process involving acquisition of energy supplies.

The purpose of this chapter is to investigate the use of waste products and solar power as sources of energy and show their potential for the Air Logistics Centers.

Methodology

To investigate the possible technologies which are available, a literature review was conducted into both waste and solar technologies. Personal interviews were also conducted with AFLC base personnel.

A specific example of the use of Refuse Derived Fuel (RDF) at Wright-Patterson Air Force Base was investigated thoroughly to determine its contribution as an energy source. Associated economical and ecological considerations were also investigated.

Although specific contributions to the ESS model were not quantified, the technologies discussed may have the potential for contributing substantially to the projected energy requirements developed in research question number 2.

The next section of this chapter presents the results of the literature review and other investigations for the utilization of waste products for energy.

Background of Utilizing Waste Products as an Energy Source

It is interesting to note that while authorities have advocated a multi-faceted policy approach to solving the United States' energy problems, little discussion has occurred with regard to one of the nation's most abundant energy resources--waste products. Technologies are emerging which are enabling the conversion of waste to energy. These processes are becoming more and more efficient and economical as the cost of conventional energy sources continue to rise. It is beginning to become apparent that waste to energy conversion processes offer great potential for solving at least a portion of our energy problem and should be exploited where feasible if the country is ever to achieve any significant level of self-sufficiency.

Solid waste has become a subject of much concern during recent years. The growth of population, products, power, pollutants and places has placed a severe strain on our environment. Discarding of eight million motor vehicles per year in the United States illustrates the impact of just one sector of our economy. Our use of land and distribution of people make old methods of "hide and forget of limited acceptance [22:299]."

Americans deposit an average of 3.5 pounds of refuse per person on a daily basis. The collection and disposal of all this refuse cost more than four billion dollars per year. An ever-increasing population, diminishing landfill space, higher transportation cost, and environmental regulations make refuse disposal a tremendous challenge that has no single or simple solution (99:95).

For years refuse has been buried in landfills, dumped at sea or burned. Solid waste is part of our daily existence; however, we are becoming more sensitive to the damange of open dumps and decomposing garbage. In 1976 the Environmental Protection Agency calculated that mulicipal solid waste including food discards, leaves, newspapers, magazines, cans, bottles, toys and other refuse, would have filled the New Oreleans Superdome from floor to ceiling twice a day 365 days a year (99:95).

Approximately 50 to 60 percent of urban waste is combustible. Of the total amount of refuse discarded, there is the potential for burning approximately ninety million tons each year. The heat could be used to produce steam for heating or driving steam turbines to produce electricity (31:306).

Although the heat content of refuse varies, in general, two tons of refuse is equal to the heat content of one ton of coal (31:306). The heat content of the total combustible refuse has been estimated from a low of 1.3 percent (31:306), to a high slightly less than 10 percent of the total energy used in the United States (22:330).

Much of the waste is dispersed in small towns or farms; however, in urban areas it may be practical to use waste as fuel for generating electricity and/or steam (31:306).

The purpose of the next section is to investigate the advantages and disadvantages which have arisen by utilizing Refuse Derived Fuel (RDF) at various facilities and to explore the possibilities of utilizing this form of energy generation within the Air Force Logistics Command ALCs.

Discussion

Composition of Refuse

Municipal waste composition in the United States varies according to the size, location and type of neighborhood, time of year, and the weather. For example, rural communities have more food and yard waste but less paper content than metropolitan areas. The National Center for Resource Recovery has found that a typical load of organic and inorganic waste breaks down like this (99:98):

1. 35 percent paper,
2. 16 percent yard wastes,
3. 15 percent food wastes,
4. 10 percent metals,
5. 10 percent glass,
6. 4 percent plastics
7. 3 percent rubber and leather,

8. 2 percent textiles, and

9. 5 percent miscellaneous.

It is interesting that we Americans because of our passion for things like fancy packaging produce refuse which has a much higher ratio of burnables than the British do--50 percent against 30 to 40 percent (33:85). Refuse definitely has national characteristics which varies with the living standards and refuse-disposal habits of societies.

A recent experiment by Flakt, Incorporated of Sweden was conducted to determine if American and Swedish domestic refuse were similar. Two tons of garbage plucked from a landfill in New Jersey were air-freighted to Stockholm for testing at a resource recovery demonstration plant operated by the Flakt Group. From a U.S. marketing standpoint, the tests were necessary because the demonstration plant was designed around the concept to recover components of refuse peculiar to Sweden. If the Flakt resource recovery system were to be suitable for the American market, the elements recovered from the American refuse would have to be of similar type and percentage as those recovered from Swedish household refuse (44:1). Although the experiment raised quite a few eyebrows from skeptical onlookers, the findings were conclusive that the American and Swedish refuse were very similar (44:1).

Methods of Recovering Energy from Refuse

At the present time there are three primary schemes for recovering energy from solid waste: (1) direct heat recovery from special incinerators (see Figure 12); (2) supplementary fueling of power plants with waste materials, and (3) conversion of the waste to synthetic fuels (25:307). A fourth, and new technique, which may have universal application is fluidized-bed incineration (22:328).

Most of the incinerators built in the United States do not practice energy recovery. They utilize a refractory furnace where solid waste is burned with air. Furnaces are either a fixed hearth type or inclined rotary kilns. New incinerators are now being built to recover heat in the form of steam, instead of discharging the combustion heat to the atmosphere as hot flue gas. A simple form of energy recovery is to extract the heat from the flue gases to make low pressure steam (102:4). A more effective type of unit uses furnace walls made of closely spaced steel tubes welded together, with water or steam circulated through the tubes to extract heat generated during combustion. This procedure provides heat recovery and also allows a major reduction in air requirements, thus reducing the size of air pollution control equipment and other facilities (103:4).

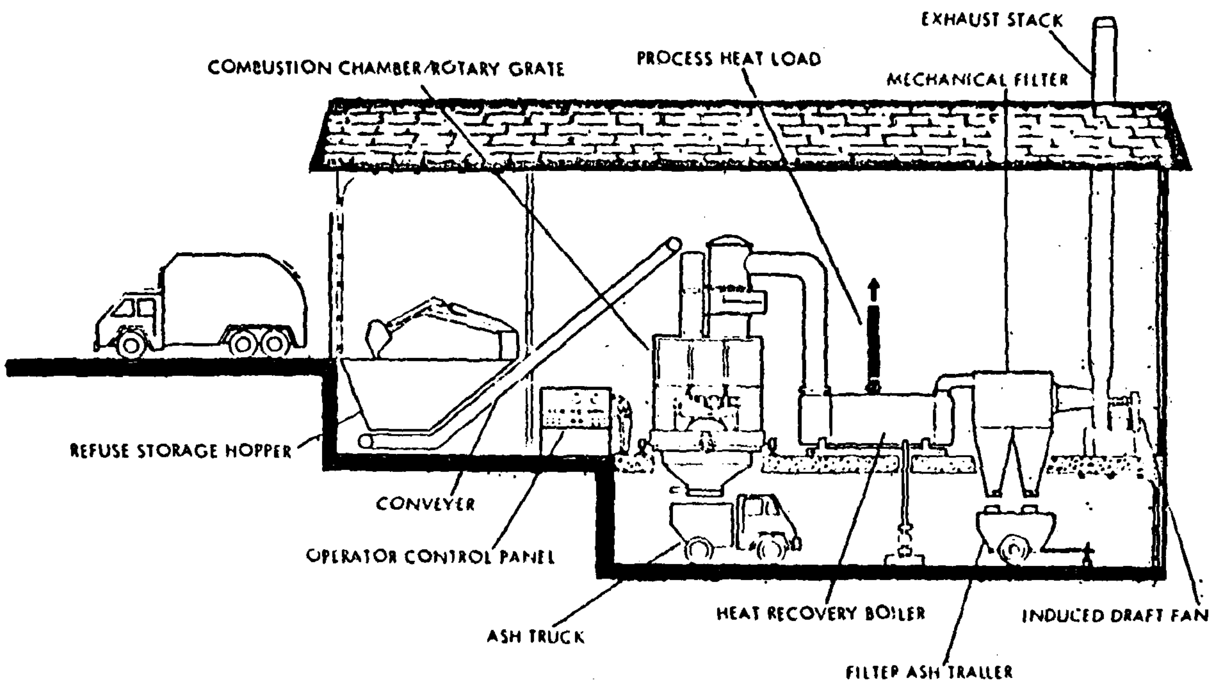

Fig. 12. Schematic of Rotary Grate Furnace System [90:15]

Supplementary fuel firing involves the simultaneous injection of solid waste, which has been shredded and/or pelletized, together with pulverized coal to form a combustible mixture. This mixture can be burned to produce low pressure steam to generate heat or for high pressure steam to produce electricity (22:329).

Conversion of waste to synthetic fuels involves the process of pyrolysis. Pyrolysis is the process of converting as-delivered or processed solid waste to a low-Btu gasseous or liquid fuel for firing in existing steam generators (25:25). In pyrolysis the waste material is exposed to heat in an atmosphere deficient in oxygen. The organic material in the waste is thermally decomposed into a usable energy form. Liquids, gases and carbonaceous char are all possible energy forms from pyrolysis. The form and characteristics of the fuel fraction is a function of the operating characteristics of the particular system as well as on the waste being processed (76:7). Pyrolysis provides liquid-fuels which are particularly attractive because of the ease with which this form of energy can be stored (102:7). From an energy yield standpoint, gas pyrolysis offers an advantage over oil pyrolysis; however, a gas pyrolysis plant is best adapted to a location near a large energy user in order to minimize pipeline and storage cost (53:3). An example of a pyrolysis type resource recovery and energy conversion is shown in Figure 13.

In fluidized-bed incineration the combustibles (pulverized coal and RDF) are suspended in an air stream with an inert granular material forming the permanent bed (22:329). Very efficient burning can be achieved with well prepared combustibles (22:329).

Resource Recovery

Often the term resource recovery is used when discussing supplemental fueling of power plants using RDF. Resource recovery describes the systematic extraction of glass, paper and metals from piles of waste. Massive machines ingest the waste, sort it by size and weight, shred, magnetize, air blast and treat it with chemicals. Some of the materials are recycled for the manufacture of new cans, bottles, and paper. Other solid waste is used as RDF to generate energy (99:95).

Energy Avoidance by Resource Recovery

The use of raw materials and energy can be dramatically reduced by recovering metals and other waste products. Unfortunately, at the present time only one-fourth of the scrap which the steel industry recycles comes from junkyards, dumps, and recycling centers. The remainder of the scrap comes from the steel mill itself or from machine shops. Some of the deterrents to a more complete

EQUIPMENT LEDGEND
1. Conveyor
2. Reject Bin
3. Shredder
4. Magnetic Separator
5. Ferrous Metal Bin
6. Shredded Refuse Storage
7. Refuse Dryer
8. Reactor
9. Condenser
10. Clarifier
11. Oil Transfer Tank
12. Product Oil Storage
13. Sludge Storage Tank
14. Oil/Water Separator
15. Cooling Tower
16. Metal/Char Separator
17. Steel/Aluminum Separator
18. Furnace
19. Product Gas Scrubbers
20. Product Gas Filter
21. Flue Gas Scrubbers
22. Waste Water Treatment

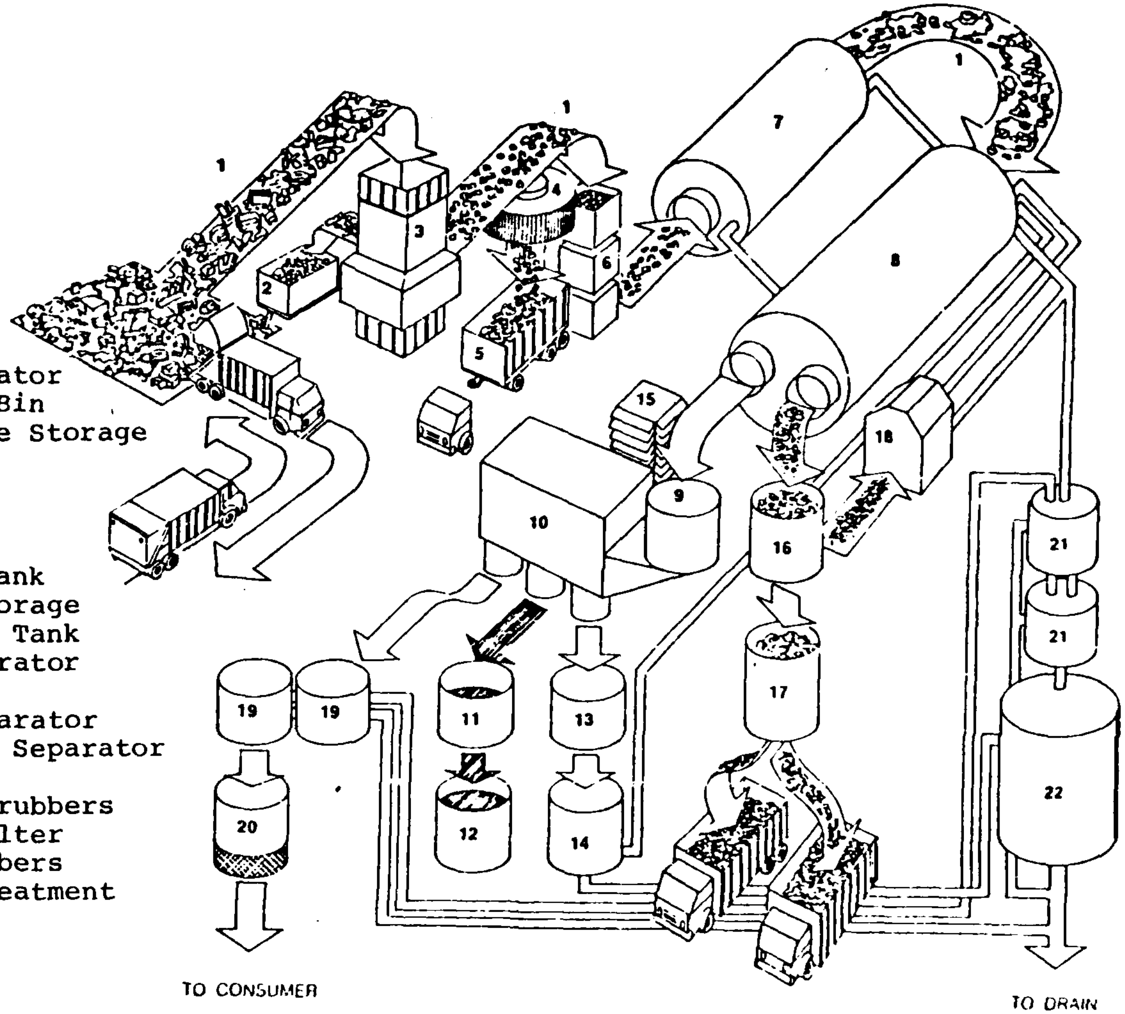

Fig. 13. Enterprise Company Resource Recovery and Energy Conversion System [25:41]

recycling of steel include: transporation costs, depletion allowances for raw materials, and the reluctance of steel-makers. It is possible to save over 50 percent of the energy for manufacturing steel by recycling (31:386).

Plastics can be recycled and would save as much as 75 percent in energy savings.

> This requires that each type of plastic be separated from the rest, an entirely impractical goal in the foreseeable future because the densities and other physical properties of various polymers overlap too much [31:387].

Recycling aluminum would allow the savings of over 90 percent of energy to produce new products. The potential is obviously enormous if resource recovery were better utilized. This potential is provided in Table 10.

TABLE 10

ENERGY SAVINGS FROM RECYCLED MATERIALS IN THE UNITED STATES (31:387)

Material	KWH Saved/Ton of Recycled Material	Est. Total Savings if all Material was Recycled-KWH
Paper	4210	50×10^9
Steel for Automobiles	7000	100×10^9
Aluminum Beverage Cans	49000	7.2×10^9
Steel Beverage Cans	7000	34×10^9
Total		191.2×10^9

If all these savings were achievable by means of recycling, approximately 10 percent of the electrical consumption in the United States could be conserved each year (31:388). A strategy that encourages the recycling of waste metals and other materials would not only be conserving of energy but also conserving of raw materials.

Examples of Current Resource Recovery Projects

Located at Ames, Iowa is the first on-line facility in the United States which was designed for producing electricity from solid waste. Over 20 percent of the electrical requirements at Ames, a city of approximately 30,000, has been provided from this municipally-owned installation since 1972 (44:1).

North Little Rock, Arkansas has also demonstrated that energy recovery is practical in smaller communities. Two small modular incinerators in a facility that cost only 1.5 million produce steam from garbage for a food preservation plant 1,000 yards away (99:98).

A 652-bed Bridgeport, Connecticut hospital found that its new heat recovery system cut $25,000 from its fuel oil bill in a four-month period.

> Installed during the fall of 1978 along with a new incinerator, the heat recovery system reclaims heat from flue gases from one 24,000 and three 30,000 #/hr. incinerators [15:1].

The new 920 #/hr. incinerator was installed to comply with state air pollution control codes. Reclaimed heat preheats boiler feedwater, raising its temperature from 224 to 280 degrees F, and reducing the amount of fuel required for feedwater heating by approximately 320 gallons per day (15:1).

William H. Rorer, Inc., a manufacturer of pharmaceuticals, has estimated that it will save over $100,000 per year by converting 1,600 tons of trash into thirteen and one-half billion Btus of heat. The heat is used for both process and comfort heating purposes. The system is pyrolytic and uses a two-stage incinerator that is able to burn virtually any combustible waste without generating smoke. When the charge is burned under oxygen-lean conditions, certain methane-like gases are driven off, and rise into a secondary chamber referred to as the thermal reactor. Here additional oxygen is added to support combustion and both smoke and gases are consumed, leaving only carbon dioxide and water vapor as residue.

> As this occurs, temperatures in the stack rise to 1800-2000 degrees F, and the heated air is passed through a boiler, where it gives up its heat to the water, converting it into steam. The steam at 90 psig, is then piped into the plant [75:8].

Output of this system is over 5 million Btus per hour (75:8).

Hooker Chemical Company has spent $65 million on a waste-to-steam system and hopes to get enough energy to supply about 10 percent of the power required at its Niagara Falls installation (99:98). Long Island Lighting Company is now buying electricity from a $73 million resource recovery plant in Hempstead (99:98).

The Navy has been deriving steam energy from recycling solid waste since 1967 in the Norfolk Salvage Fuel Boiler Plant. This installation has shown the effectiveness of waterwall/refuse-fuel boilers of realtively small size (25:1). From this project it was estimated that with an input of fifty tons per day, waterwall boilers can be justified. Below this amount, waterwall systems become prohibitively expensive (90:1).

Use of Resource Recovery within the United States Air Force

At the present time, the only Air Force base utilizing RDF is Wright-Patterson AFB, Ohio. Wright-Patterson AFB has been using RDF for more than a year at its steam plant (Building 770) in Area B. The RDF is mixed on a 1 to 1 ratio (by volume) with stoker coal and burned to produce steam. About 80,000 #/week of RDF is used at the present time. The RDF is produced by Teledyne National Corporation in Baltimore, Maryland and transported by truck to Wright-Patterson AFB (85).

Originally it was thought that the RDF could be transported by train; however, in the fourteen to fifteen days of transit, too much shaking and vibration resulted in the RDF being unsuitable for use. The RDF shipped by rail was too compacted and a higher than acceptable percentage of fines resulted.

Presently the use of RDF is a losing proposition due to RDF cost and transportation (85). At the present time Wright-Patterson AFB discards about 10,000 tons per year of refuse. One might think that this amount would be sufficient to justify a base RDF plant; however, to supply sufficient feedstock, over 50,000 tons per year are necessary. The local communities still find that landfills are the most economical means of disposing of waste; however, with the total cost for collection and disposal of fifty to seventy-five dollars per ton, the economics of a local RDF plant are beinning to look attractive (85).

The primary problems encountered thus far by using RDF (besides cost) have been smoking, clinkers, and slow corrosion (85). Wright-Patterson AFB will continue to use RDF at least through 30 September 1981 when the Teledyne contract expires (85). By that time it is anticipated that local firms will offer a similar product at a much reduced cost.

Problems Found by Processing Solid Waste

In recent months the experience of using solid waste reclamation has been encouraging; however, since it is a relatively new technology in the United States, numerous problems have arisen in the past.

At the New Castle County Solid Waste Reclamation Plant in New Castle, Delaware, solid waste from an area with a population of about 400,000 is processed. This facility has processed over 800,000 tons of solid waste by a conventional shredder operation (61:51). With their relatively long-term experience using shredding as a first step they found several disadvantages (61:52):

1. Explosions
2. Excessive shredder wear due to glass
3. Low heating value fuel
4. High ash in fuel

By far the most significant problem was with explosions--over thirty since startup. In June 1973 a major explosion was caused by the injection of twelve pounds of smokeless power. A trapshooter who reloads his own shells had probably become concerned that his powder was damp and threw it away. In 1974 an explosion equivalent to about sixty sticks of dynamite caused about $250,000 damage but there were no injuries due to good explosion venting (61:52).

To minimize shredder plant problems the following steps were taken (61:52):

1. Venting for explosion release
2. Water fog for explosion suppression

3. Automatic explosion detection
4. Use of trommel screens
5. Screening after shredding

Environmental Considerations

A major consideration in the use of alternate energy forms such as refuse is the effect upon the environment. A major pollutant associated with coal is sulfur emissions. The sulfur content of coal ranges anywhere from .6 percent (low sulfur West Virginia coal) to 2.5 or 3.0 percent for Ohio coal (85). A thorough review of literature (see Table 11) shows a consistent average sulfur content of 0.1 to 0.2 percent in U.S. refuse (53:7). It has been estimated that sulfur inputs to the environment could be reduced by a factor of from 5 to 15 with the use of refuse. Additionally, it has been estimated that 95 to 100 percent of the sulfur in coal or oil finds its way into flue gases as sulfur oxides while data available for refuse incinerators indicate that only somewhere between 25 to 50 percent of the refuse input sulfur is released as sulfur dioxides. The reason for this is that a significant portion of the sulfur in trash is of an inorganic salt or fixed form. One author estimated that if all refuse now available in the United States were to displace coal with a 2 percent sulfur content, that over two and one-half million tons of sulfur dioxide would be eliminated from the atmosphere

TABLE 11

SOLID WASTE/COAL COMPARISON (102:21)

	Refuse %	Coal %
Moisture	19.60 - 31.30	6.20 - 10.20
Carbon	23.50 - 33.50	61.30 - 66.20
Hydrogen	3.30 - 4.70	4.50 - 5.50
Nitrogen	0.19 - 0.37	0.83 - 1.31
Chlorine	0.13 - 0.32	0.03 - 0.05
Sulfur	0.19 - 0.33	3.06 - 3.93
Ash	9.43 - 26.83	9.73 - 10.83
Oxygen	15.37 - 31.90	9.28 - 16.10

annually (53:7-8). One disadvantage of the low sulfur content of refuse is illustrated by the following quote:

> Where relatively low-sulfur coal is being fired with exit flue gas temperatures greater than about 270-280 degrees F, the addition of low sulfur refuse may introduce, or make worse, resistivity problems due to the lack of sufficient sulfur trioxide conditioning agents naturally present from the coal sulfur. In this situation, gas conditioning with sulfur trioxide or similar additives, or extensive precipitator modification might be necessary to meet emission regulations [102:144].

The foregoing conclusions with respect to reduced sulfur dioxide levels have been upheld at Wright-Patterson AFB. The utilization of refuse derived fuel has garnered Wright-Patterson AFB a 50 percent reduction in sulfur dioxide emissions (86).

A second form of air pollution causing concern, particulate emissions, result from the incineration of coal, oil and various forms of RDF. The size and amount of the particulates depend upon the design, operation and refuse ash composition.

> A poorly designed or operated incinerator may emit carbon particles (usually referred to as soot), and inorganic (mineral) type ash will contain a significant quantity of combustibles. Data from six New York City incinerators showed a range of 6-40 percent in the combustible content of furnace particulate emissions [102:116].

Some authors (53) contend particulate emissions could be 120,000 tons per year less if a refuse program were undertaken. If shredded and fired in suspension (similar to the St. Louis operation) refuse would generate more fly ash, but not to the extent of 80 percent or more of its inert content, which is typical for coal (53:8). Although the previously cited authors claim decreases in particulate emissions, Wright-Patterson AFB experience has not shown a reduction. Mr. Tom Shoup of Wright-Patterson AFB has indicated that the particulate level has remained about the same since the introduction of RDF operations.

Poor refuse combustion can result in emissions of carbon monoxide, hydrocarbons, oxygenated hydrocarbons, and a series of other complex compounds. Although specific figures were not available, Mr. Shoup indicated an 85 percent hydrocarbon reduction from utilization of RDF.

Experience gained from present and past projects has revealed minor quantities of sulfur oxides, ammonia and halide gases generated from the sulfur, nitrogen and halide (chlorine, bromine, flourine) content of the waste material. Nitrous oxides result from the nitrogen content of the waste or high-temperature oxidation of nitrogen in the air (102:150). Wright-Patterson AFB has not experienced a significant increase in nitrous oxide emissions due to the RDF operation (85).

In addition to the emissions indicated above, hydrogen chloride emissions have been causing increasing concern. These emissions are due to an increased disposal of polyvinyl chloride (PVC) and other halide-containing plastics and aerosols. In addition to possible health effects of toxic chemicals, the possibility of corrosion to metal surfaces in steam generating systems have caused officials concern. The possibility of boiler corrosion due to hydrogen chloride is an expressed concern of Wright-Patterson AFB officials; however, the RDF usage period has not yet been long enough to ascertain if there actually is a problem in this respect (85).

Although air pollution is the primary concern in RDF operations, other environmental objections have been raised. One objection stems from the volume of traffic involved in and around the RDF processing center. A 2,000 ton per day RDF recovery facility would receive about 250 large truckloads of refuse daily. Local concerns involve the odors and pathogens associated with the refuse. As previously mentioned, some RDF operations employ shredders, classifiers, etc. These operations can cause noise pollution problems in the local area if precautions are not taken. A final concern with the processing center is what happens to the garbage should the refuse processors go on strike or when the equipment breaks down. Where does one put a 1,000 tons (Wright-Patterson AFB requirement for RDF operations) of garbage per day once the landfill operation has been reduced?

Although RDF provides definite advantages in reducing certain emissions, we must refrain from declaring it a panacea for emission reduction. Research indicates that RDF has a tremendous future energy potential and present technology is adequate to remove any harmful effects introduced by RDF or its associated procedures.

Economic Considerations

The use of RDF at Wright-Patterson AFB appears to be a losing proposition at the present time (see Table 12). The RDF is currently produced on contract by the Teledyne National Corporation of Baltimore, Maryland and transported by truck to Wright-Patterson AFB. As one can see From Table 12, RDF could be cost-effective in terms of dollars per Btu if the huge transportation cost could be

TABLE 12

RDF COST INFORMATION AT WRIGHT-PATTERSON AFB (85)

Type Fuel	Virginia Coal	Ohio Coal	RDF
Cost/ton	$53.00	$35.00	$27.00
Transportation cost	$12.00	$ 7.00	$53.00
Total cost/ton	$65.00	$42.00	$80.00
Btus/lb	13,000.00	13,000.00	6,500.00
Ash disposal costs/ton	$ .55	$ .55	$ 1.50
Sulfur dioxide content (%)	1.0	3.0	0.1

eliminated. Local officials are confident that interest can be generated for the opening of a local RDF processing plant. The associated transportation costs with a local RDF processing operation are estimated to be in the two- to three-dollar per ton range.

Table 13 illustrates the cost-effectiveness of using RDF at Wright-Patterson AFB. Wright-Patterson presently uses approximately 110,000 tons of coal annually for its heating operations. Plan 1 (Table 13) represents the cost of burning 110,000 tons of Virginia coal at $65 per ton. Virginia coal is burned due to its low sulfur content. The burning of the lower cost Ohio coal would result in a violation of federal emission (sulfur dioxide) standards.

TABLE 13

COAL AND RDF ANALYSIS (85)

Plan	Annual Usage (Tons)	Cost/Ton	Total Cost
		Coal	
1	110,000	$65.00	$7,150,000
2	82,500	$65.00	$5,362,500
3	82,500	$65.00	$5,362,500
4	82,500	$42.00	$3,465,000
5	82,500	$52.00	$3,465,000
		RDF	
1	0	0	0
2	55,000	$80.00	$4,400,000
3	55,000	$30.00	$1,650,000
4	55,000	$80.00	$4,400,000
5	55,000	$30.00	$1,650,000

Plan	Combined Cost
1	$7,150,000
2	$9,752,500
3	$7,012,500
4	$7,865,000
5	$5,115,000

Plan 2 represents the cost of reducing the coal usage by 25 percent and making up the balance by burning RDF. AS one can see, it is not cost-effective in that cost increase by $2,612,500 over Plan 1. The reason for the increased cost is due to the $53 per ton transportation fee incurred by transporting the RDF from Baltimore. The Teledyne contract expires in 1981 and by then Wright-Patterson officials believe a local source of RDF will be available (85).

The cost of burning RDF at Wright-Patterson AFB would be greatly reduced (Plan 4) if the base burned low cost Ohio coal versus the high cost Virginia coal presently being used. Base officials believe that by using low sulfur RDF combined with high sulfur Ohio coal federal sulfur dioxide emissions could still be met. Tests will be run to ascertain this point. As energy costs become increasingly higher and burning of RDF (even at $80 per ton) will become increasingly more attractive.

RDF burning at Wright-Patterson will become a paying proposition if a local RDF processing plant is established. Local interest in this type is increasing and Wright-Patterson AFB recently received an unsolicited proposal for an RDF processing plant. Base officials believe the cost of locally produced RDF would be approximately $30 per ton delivered (85). Plan 3 illustrates an RDF operation at Wright-Patterson AFB with a local supplier. If Wright-Patterson AFB continued to use Virginia coal under this option a savings of $2,750,000 would be realized over present operations (Plan 2).

The ultimate operation at Wright-Patterson would be Plan 5. The plan involves the burning of low cost Ohio coal and locally produced RDF. Over $4.5 million dollars could be saved at Wright-Patterson AFB alone if this option were used, and this does not even consider the cost savings associated with not having to haul 55,000 tons of refuse to the landfill. The cost to dispose of refuse in the city of Dayton is estimated to fall in the $50 to $60 per ton range for the total refuse cycle. If one-half of the $60 per ton figure were saved by burning refuse rather than transporting it to a landfill, a $1.7 million (55,000 tons x $30) opportunity cost could be realized at Wright-Patterson AFB. Additionally, one can expect landfill costs to increase as landfills are located farther and farther away from the city because of the scarcity and associated expense of land close to the city.

Although RDF seems to be the new fuel of the hour at Wright-Patterson AFB, this does not mean that there are not better alternatives available. Table 14 was completed by the city of Charleston, South Carolina in an attempt to determine the best method for utilizing refuse as an energy source. A high score for a particular attribute is superior

TABLE 14

PROCESS RAW SCORES (25:32)

	Waterwall Incinerator	Purox Pyrolysis	Densified RDF	Row Sum
Technical Reliability				
Proven art	5	3	2	10
Predictable wear	5	3	2	10
Subtotal	10	6	4	
Practicability				
Complexity	5	4	1	10
Maintenance and repair	4	4	2	10
Management impact	4	5	1	
Subtotal	13	13	4	
Conservation				
Energy	5	3	2	10
Materials	3	3	4	10
Water	3	9	4	10
Subtotal	11	9	10	
Environment				
Air	3	5	2	10
Water	3	3	4	10
Land	4	4	2	10
Nuisance	3	4	3	10
Subtotal	13	16	11	
Experience				
Operational history	7	2	1	10
Number of facilities	5	3	2	10
Subtotal	12	5	3	
Economics				
First costs	4	5	1	10
Recurring costs	5	4	1	10
Subtotal	9	9	2	
	68	58	34	

to a low score. Selection of the relatively superior process was made by summing the process subtotals. According to the city of Charleston, waterwall incineration had a slight edge over the pyrolysis process. Densified RDF (the type used at Wright-Patterson AFB) came in a poor third in almost every category. While the Charleston study does not prove that wright-Patterson is using an inferior process, it does suggest that base officials might be wise to explore alternatives to densified RDF.

The next section of this chapter is concerned with other waste to energy recovery technologies that are currently emerging. AFLC Command officials may be interested in exploring these other techniques for use in the ALCs' industrial facilities and processes.

Other Waste Recovery Technologies Emerging

Landfill Methane

Recently the first industrial use of landfill methane gas (LMG) went on stream at Hoeganaes Corporation in Riverton, New Jersey. Hoeganaes will receive approximately one million cubic feet of methane gas per day. The methane will be used to heat thirty-ton ladles employed in the manufacture of metal powders (40:2).

The LMG is pumped to the plant from wells built on the landfill by the Public Service Electric and Gas Company of New Jersey. Sanitary Landfills, Inc. owns the landfill which is located adjacent to the Hoeganaes plant. Although methane gas is being utilized in California also, it is not used in industrial operations. This operation is the first use of LMG on the East Coast (40:2).

"Hoeganaes is proud to be one of the nation's pioneers in seeking and employing new energy sources," said R. Russell Fayles, President of the company.

> This alternative source will help conserve valuable natural gas and offers additional protection to the local environment and provides the company with an anticipated committed source of energy for the next decade, or as long as the landfill continues to generate gas [40:2].

Hoeganaes invested more than $100,000 in the LMG project even though they had no assurances of the amount or longevity of the methane supply. The decision that LMG could be a viable alternative energy source was made in March 1976, after LMG had been discovered to be migrating from the landfill to an adjoining farm where it endangered certain crops. Three and one-half years were needed to complete the project (40:2).

Hoeganaes believes that LMG will provide about 15 to 20 percent of its energy use each year. Once the project is evaluated for supply and quality, the company hopes to use the gas in more areas of the plant's operations, such as in furnaces and in heat-treating applications.

Anaerobic decomposition of refuse materials results in the creation of methane gas. It consists of carbon and hydrogen created by the decomposition process. Approximately two years are required for the creation of methane once disposal at a landfill site has started (40:2).

Project to Convert Scrap Tires to Energy

American drivers go through rubber tires at an awesome pace. There are over two billion tires already discarded at domestic dumps and landfills. Tires are continuing to pile up at a rate of 200 million a year and, therefore, disposal is proving to be an increasingly difficult problem (35:1).

Energy Recovery Research Group, Inc. (ERRG), together with Barnard and Burk, Inc., the Pasadena-based engineering and construction firm, have embarked on a project designed to convert scrap tires to usable energy products. ERRG is currently operating a pilot plant utilizing the pyrolysis technique in Portland, Oregon. "The plant incorporates a proprietary conversion system for converting shredded scrap tires to high yields of recoverable energy products [35:1]." The system is nonpolluting to the environment and thermally self-sufficient. "Barnard and Burk is presently scaling up the process design to a 20-ton-per-day plant, with a 50-ton-per-day unit next in line [35:2]." Work is also under way to prepare engineering and design specifications and drawings suitable for the

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fabrication and erection of skid-mounted units capable of being shipped throughout the world.

Scrap tires have a heating value of about 14,000 to 15,000 Btus per pound which is equal to or greater than coal. "This high heating value would appear to make scrap tires a viable alternative energy source, and ERRG's pyrolysis plant is one way to produce that energy [35:2]."

Power from Waste Heat

A waste heat conversion package developed by the English firm of Clark Hawthorn, has entered service with the Electricity Department of the Douglas Corporation on the Isle of Man, just off the English coast. The system, called the "Seajoule" was introduced in the United States and Canada in 1978. The system was designed to conserve energy and save cost by using the waste heat in diesel engine exhaust gases to generate electricity without burning additional fuel (78:5).

> The "Seajoule" system was installed at the Douglas Corporation's Pulrose Power Station, where it works in conjunction with four of the station's "Mirrlees KV 12 Major MK 1 diesel generating sets," each rated at 3.5 Megawatts to produce 1,000 Kilowatts of additional power. The complete "Seajoule" package supplied by Clark Hawthorn is comprised of 1MW power module and four 250 KW exhaust gas economizers, together with all associated piping, valves, and control equipment [78:5].

The "Seajoule" is equally adaptable for land based and marine applications. It maximizes waste heat recovery by automatically matching the electricity output to the heat available. The system should save about $280,000 annually in fuel cost (78:5). The initial cost of the project should be recouped within four years because the reduction in the station's fuel oil consumption is estimated at 267,000 gallons per year (78:5).

Used Oil as a Source of Energy

Used oil offers the promise of providing a contribution to the energy picture. Used oil which is normally considered a highly pollutant waste, can be reclaimed and rerefined into base oils or it can be burned as an energy source. Table 15 depicts the worldwide losses of petroleum products (106:3).

TABLE 15

PETROLEUM LOSSES IN 10^5 TONS (106:3)

Tankers (Routine Operation)	0.53
Other Vessels	0.50
Offshore Drilling	0.10
Accidental Spills	0.20
Refineries and Petrochemical Institutes	0.30
Automobiles	1.80
Industry	1.30
Total	4.73

The manner in which this oil is reused depends upon economic factors and legal restrictions.

Used motor oil has the combustion properties of having a high caloric power (close to fuel), low freezing point and low sulfur content. The primary disadvantages of used oil include the presence of metallic impurities, an ash ratio of 0.8 to 1.5 percent, and an asphalt residue of 4 to 7 percent (106:7).

The combustion of one ton of used oil will permit a saving in crude oil of 0.900 to 0.950 tons--the efficiency being affected by the presence of impurities (106:7). Conventional burners can use used oil only in small proportions. Specifically adapted burning assemblies can be adapted to burn this energy source exclusively.

Waste Sawdust for Energy

Bill Burnham, the plant superintendent and electric-utility specialist at the Southern Colorado Power Canon City Plant, is "blazing new trails with sawdust from local-area lumber mills [31:64]." He is feeding the wood waste mixed with coal into the plant's boilers. Currently two boilers are burning an average of about 120 tons of sawdust a day. Burnham notes that the process is nothing extravagant.

> The sawdust simply falls out from the back of a truck and down through a grating into a hopper with the coal. Then it is conveyed as a mixture with the coal into the boiler and burned [66:64].

The sawdust is hauled in specially equipped semi-trailers with canvas tops. Each trailer is equipped with a full-width conveyor belt on the floor, which pulls the sawdust out of the truck's back door. The trailer is parked on the grate over the hopper at the plant.

Burning a ton of coal produces from 200 to 600 pounds of ash in the boiler. Ash is abrasive and erodes the metal. On the other hand, sawdust produces about 60 pounds of ash per ton.

> Anything you can do to cut down the amount of ash just lengthens the life of everything. Also, with the quantity of ash reduced, there's less ash-handling labor and equipment involved [66:64].

Sawdust consumption has increased gradually at the plant and is now averaging about 100 tons/day. "About 120 tons per day is the maximum we can burn," Burnham says. "If we were to burn more sawdust than that, we'd have to make equipment conversions, and that takes dollars [66:64]."

Sawdust varies in burning qualities. If sawdust has a high moisture content, it burns less efficiently, also the higher the moisture content, the lower the Btu rating. One ton of dry sawdust produces about 10 to 11 million Btus. Sawdust is less than half the cost of coal and is currently about $6 per ton. In 1978 the savings obtained by using sawdust amounted to 11.3 cents per 1-million Btus.

Another advantage is that burning sawdust causes less air pollution than coal not only because it contains less ash, but also because the sulfur content is one-fifth that of the Colorado subbituminous coal used in the plant. "This is despite the fact that Colorado coal is a low-sulfur coal with an average sulfur content of only 0.55 percent [66:64]."

Densification

> A fuel with a high mass energy density and volume energy is preferable to a fuel with low values because it is more efficient to store, ship and burn. Combustion efficiency increases with increasing fuel density and decreasing moisture content [50:K-1].

There are currently five forms of biomass densification being practiced commercially and they involve: pelletizing, cubing, briquetting, extrusion, and rolling-compressing. Products vary in size and appearance from one-fourth-inch diameter pellets to eight-inch and seven-inch diameter rolls. The process is dependent on heat input. Heat softens the ligin (a "waterproof glue" that holds the cellulosic materials, or biomass, together) in material so that it can be molded, and reduces the moisture content to approximately 10 to 25 percent (50:K-1).

> The process of densifying biomass shows promise of providing a dry, uniform, easily stored and conveniently shipped fuel from the wide variety of residues produced in agriculture, forestry, and food processing. Compared to coal, densified biomass is clean, easy to handle and burns with low ash and sulfur emissions [50:K-1].

About 7 percent of the energy in the feedstock is consumed during the process of densification. Densified wood costs from $1.20 to $3.40 per million Btu. Widespread use of densification could generate a comodity fuel market capable of supplying both small and large fuel users. Pellets are also suitable for use in gasifiers (50:K-1).

Truck Waste Heat Recycling

Under field trials is a waste heat recycling system designed to give diesel trucks more horsepower, better mileage and less emissions.

> Under laboratory tests, the system developed by Thermo Electron Corporation with DOE funding boosted energy efficiency by 16 percent. Under full development the system is expected to provide a 15 percent improvement in fuel efficiency and a 15 percent reduction in emission levels as measured in trucks [103:4].

The project being coordinated by the Division of Transportation Energy Conservation, Office of Conservation and Solar Applications, is aimed at the long-haul, heavy-duty truck. The DOE points out that the typical long haul diesel truck annually travels 100,000 miles and consumes about 22,700 gallons of fuel at an average rate of 4.4 miler per gallon.

> A 15 percent reduction could save some 3,400 gallons of fuel each year and about $1,900 in fuel costs. For the trucking industry as a whole, the fuel savings could total 3.95 billion gallons of diesel fuel per year or the equivalent savings of 223 million barrels of crude oil [103:4].

The waste heat is used to vaporize an organic working fluid which, in turn, drives a multistage turbine to provide additional shaft power to the engine power train. Once leaving the turbine, the fluid is cooled, condensed and returned to be heated and recycled again. Since the system is sealed, the fluid is continually reusable. Known as the "bottoming cycle," the system works best for heavy duty trucks on long hauls at constant speeds. Known as the Diesel-Organic Rankine compound engine, it is designed for use on old or new trucks and should be commercially available during the mid-1980s. The system is expected to pay for itself in fuel savings in one year (103:4).

Vehicles Operated on Sewage By-Product Gas

A prototype of a Sewage Gas Vehicle Fuel System, installed by the city of Modesto, California in its sewage treatment facility was unveiled about eighteen months ago. The Sewage Gas Vehicle Fuel System will enable municipalities and other agencies to operate fleet vehicles on methane gas produced during the treatment of sewage. The gas is scrubbed to remove carbon dioxide and other contaminants which are also produced along with the methane during the waste decomposition process. A high quality, clean gas results which can be used to fuel motor vehicles and other combustion equipment (108:4).

By operating vehicles on methane gas rather than gasoline, air pollution is reduced and little or no carbon build-up occurs inside the engine. Maintenance costs are reduced since spark plug and oil life are extended. The only costs that are incurred for recovering the methane are those associated with scrubbing. The basic design of the Modesto installation incorporates a two-column water scrubbing process to purify the gas.

> The unit includes a regenerator which cleans the water used in the scrubbing process so that it can be recirculated. The scrubber takes digestor gas, with a 55 percent methane content and a heating value of about 575 Btu, cleans and delivers it under pressure for later use at a 98 percent methane content with a heating value of over 995 Btu [109:4].

Five municipal vehicles stationed at the treatment facility will now be powered by waste which had previously been burned off. The vehicles will operate on equipment patented by Dual Fuel Systems, Incorporated, which permits the vehicle to use compressed natural gas while also retaining the ability to operate on gasoline.

> After a test period, additional vehicles will be considered for conversion to operate on the system. The majority of the vehicles using the system will be stationed at the facility and will refuel overnight. Other vehicles stationed at remote city locations will be able to refuel by the quick-fill method in a matter of minutes [108:4].

The potential for providing energy from the gas formed during the treatment of sewage has been known for many years; however, previously the gas had been of such poor quality that it would be employed in only a very limited way for heating or stationary engine power for the treatment plant itself. Poor quality prevented the gas from being mixed with utility pipeline gas for utilization in other industrial applications; consequently, the gas that could not be used at the treatment plant was burned off as waste. "Today, this excess gas can be substituted for high priced gasoline to reduce operating cost for mulicipal fleets [108:4]." The Modesto sewage treatment plant has the daily potential to produce the methane equivalent of 1,000 gallons of gasoline or enough fuel to handle the requirements of a fleet of more than 150 vehicles.

> As the price of gasoline continues to increase, the objective to hold down fleet operating cost becomes increasingly difficult. A development such as the Dual Fuel Sewage Gas Vehicle Fuel System goes a long way towards easing the strain on the Municipal fleet operating budget [108:4].

This technology may also offer the potential for providing a substantial contribution to the thermal requirements of the ALCs' industrial facilities and processes.

Biomass

Biomass is a term which covers anything from the raw material of gasohol (e.g., corn or sugar) to trees that can be milked of an oil-like sap (like rubber is milked in plantations now); from garbage that can be turned into gas to combustible waste chippings from forestry (33:83). Considerable discussion has previously been provided in this paper with regard to biomass type conversions; however, further emphasis is necessary with respect to waste from farm products.

> Living plants "make" 10 times as much energy each year as man consumes. They store at any one time as much as all proven reserves of fossil hydrocarbons--coal, oil and gas--combined [33:83].

The thing that biomass processes have in common is that they exploit the constantly renewable cycle of plants, which extract carbon from the earth's atmosphere, die and are decomposed, returning carbon to the atmosphere, ready for the cycle to begin again. "The final stage of the recycling is done naturally by bugs; it could be done deliberately by man [33:83]."

Total Energy Systems

Total energy systems may be developed and implemented within the next ten years on a sufficiently wide basis to become an important part of the United States energy system.

> . . . total energy or integrated utility systems are combined processing plants that generate electricity; use residual and recycled energy for heating, air conditioning, and hot water; treat water; process solid wastes and treat liquid wastes. These systems are often called cogeneration systems [31:364].

During the generation of electricity approximately 65 percent of the fuel energy content is wasted. In an integrated system, more than half of this waste energy can be recovered for productive uses. By using waste thermal energy in this manner, major reductions in fuel requirements and associated reductions in combustion products and thermal pollution are achieved.

> The total system is an integrated modular system providing the five necessary utility services for community development: electricity; environmental conditioning; solid waste processing; liquid-waste processing; domestic water [31:364].

It has been determined that fifteen quads of waste heat will be discharged to the environment this year. A total energy system is an attempt to utilize this waste heat energy for heating and other purposes. Rejected heat can also be used to aid agriculture by soil heating, for environmental control of greenhouses and other unusual applications such as aquaculture.

> While total energy systems are several years from wide use, they hold significant promise for an increase in total system efficiency. Therefore, total energy systems may become commonly used for neighborhoods or by industries or colleges within this century [31:366].

Waste Section Summary

These sections have presented a background of the solid waste problem in the United States and have discussed the potential for utilizing waste as an alternative energy source. Various methods of recovering energy from refuse were discussed with special emphasis being placed on the RDF operation at Wright-Patterson AFB. Ecological and environmental considerations were also addressed.

A separate section was devoted to a discussion of new waste recovery technologies that are emerging. Many of these technologies may offer some potential for the ALCs.

The final section of this chapter provides a look at the potential for solar power in the United States and AFLC. Many respondents who were interviewed for research question number 1, advocated further use of solar at the ALCs to gain some degree of self-sufficiency. While solar power does not offer a panacea, it may have the potential to substantially assist in a move toward self-sufficiency.

The Solar Potential for AFLC

Background of Solar Power as an Energy Source

> During most of this century, solar energy seemed to interest only dreamers, tinkerers and radicals. But because of the oil embargo, the sun has become a serious alternative source of energy. The issue has now become how much solar energy, what kind--and when [88:183].

All of our food and most of the fuel we use has been made possible by the sun through the photosynthetic combination of water and atmospheric carbon dioxide in plants. "Solar energy is the basic energy support for life and underlies the wind, the climate, and fossil fuels [31:315]."

Humankind has used solar radiation since the beginnings of time for heating their domicile, for agriculture and for personal comfort. Various forms of solar heating have been used throughout history.

Mercury and oxygen were obtained by the decomposition of mercuric oxide in 1774. The decomposition resulted by using lenses to concentrate solar rays on the mercuric oxide. In the desert of North Chile a solar distillation unit covering 4750 square meters of land was built to convert fresh water from salt water. Built in 1872, the plant operated for forty years producing six thousand gallons of water per day (31:315).

In Paris in 1878, sunlight was focused onto a steam boiler that operated an engine which provided the power for a printing press. "During the period of 1901 to 1915, several solar collectors used with steam engines of several horsepower were constructed in California and Pennsylvania [31:315]."

The examples of ingenuous uses of solar power are many; however, after the introduction of cheap fossil fuels, the incentive for utilizing solar power diminished. In today's environment of ever-increasing fossil fuel prices, mankind has once again turned to harnessing solar power.

What is Solar Power?

Many energy sources have been included under the term solar. This has caused confusion in thinking about the issue. In an effort to simplify the matter, the

Department of Energy has divided solar into eight different categories which can be organized into three major groups (88:184):

1. Thermal Applications

    a. Heating and cooling of buildings--including hot water heating

    b. Agricultural and industrial process heating

2. Fuels from biomass

    a. Plant matter, including wood and waste.

3. Solar electric

    a. Solar thermal electric

    b. Photovoltaics--solar cells

    c. Wind--windmills

    d. Hydropower--hydroelectric dams

Each category can be further broken down. For example, biomass includes wood and also technolgoies to improve yields of sea algae farms, research on new vegetable oils and gasification and manure (88; 184). Biomass was discussed in the previous chapter in the context of it being a waste product. The unifying concept of solar energy is that it is energy that arrived on the earth from the sun "recently"--during the last hundred years or so (88:185).

Solar power is abundantly available. It is essentially a nondepletable source of energy and it is cost-free in its original radiation form (1:316). Naturally, there is a significant cost for the capital plant required for converting solar energy to other forms of energy. Solar devices hold promise not only for the economically developed world but also the "third world" nations (31:316).

The average annual insolation for the Continental U.S. amounts to about 1600×10^{12} Watts. Assuming that one-half of the total time period available during a year was used for converting solar power to useful energy, an energy quantity of 2.4×10^{19} Btu would be available (31:317). During 1975 the United States consumed about 78×10^{15} Btu; therefore, the solar energy available is about 308 times that required by the nation (31:317).

Only small amounts of air and water pollution and negligible thermal pollution are generated by solar conversion systems. A desert area of 120 km by 120 km would receive enough solar energy each year to meet the entire estimated U.S. energy demand for 1985 (94:289).

> Actually, however, a much larger area would be required since available solar energy conversion devices are not totally efficient. The conversion efficiency of water and air panels is less than 70 percent and is only 10 percent for photovoltaic solar cells or thermionic devices [94:289].

Differing Opinions on Near Term Solar Contributions

A wide range of opinions currently exist concerning the contributions that solar power can offer for the United States. The organizer of the International Sun Day believes that 40 percent of the country's energy could come from solar by 2000 if dramatic moves are made now. Disagreeing, the editor of World Oil said that solar will have the impact over the next quarter-century of "a mosquito bite on an elephant's fanny [88:183]."

U.S. News and World Report writing in December, 1979 indicated that sources of energy--from the sun, wind, and plant life--are not expected to play a major role in meeting U.S. energy needs for a long time. The exception noted was in the heavily forested areas of New England where wood is an important source of heat for homeowners and industry (116:64).

Newsweek notes that "to many Americans the promise of cheap, clean, renewable solar power is the most attractive energy solution of all [1:32]." However, existing solar technology is still too primitive to make a dent much before well into the next century [1:32]." Newsweek notes that at present, the hot-water, space and industrial process heat that solar can provide cannot be stored efficiently. These systems also require the added expense of conventional backup systems to provide power on cloudy days (1:32). High-technology solar solutions like instant electricity from photovoltaic cells are useful in isolated circumstances but are too costly for every-day applications. Although sudden breakthroughs in technology are always possible, large-scale applications for power generation are remote (1:32). Newsweek does believe that the energy-saving potential of sun power should be exploited for all it is worth and that lending policies should be changed to give breaks to builders who construct houses using passive solar designs. The government should also broaden tax credits to nurture the infant solar industry (1:33).

Tony Velocei writing for Nation's Business, states that

> . . . solar technology, which may provide up to three percent of the nation's electricity by 2000, is complicated by uncertainties relating to technology development, market economies, and government policies [109:36].

A more optimistic perspective is made by Modesto A. Maidique of Grumman Energy Systems. He believes that new technology is not required to realize solar's potential. The kind of relatively low level technology needed for a 20 percent contribution is already here, or very close to being here (88:183). He believes that a more responsive public policy is required to overcome the obstacles to near-term solar energy. Government support for solar has increased substantially in the past few years; however, the support has been weighted much more toward high-technology research and development projects, which may or may not be able to make a contribution in the twenty-first century. The near-term, more certain small solar opportunities are not yet receiving support commensurate with their likely potential (88:184).

It is difficult to estimate how much of America's energy needs could be derived from solar by the year 2000. Since estimates vary widely and different analysts define solar in various manners, comparisons are hampered. Some analysts begin and end with solar heating while others include all solar options except hydropower (88:210). Recently analysts have begun to develop a consensus regarding the solar definition which is similar to the one previously provided in this section. After making adjustments to the definition provided, projections still ranged from 7 to 23 percent by the year 2000 (88:184). This is shown by Table 16.

The primary reasons for the differences come from the various assumptions made about the following five variables which are difficult to predict (88:211):

1. Prices of competing fuels.
2. Overall levels of domestic energy consumption.
3. Rate of federal investment on solar energy.
4. Rate of technological advancement of solar technologies.
5. Rate at which institutional barriers to solar will be overcome.

The third factor which involves federal policy is the most controllable. Unfortunately, there is still much confusion over how much the government should influence the development of solar power.

TABLE 16

SOLAR CONTRIBUTION BY YEAR 2000* [88:211]

	Solar Energy (oil equivalent mdb)	Total Energy Consumption (oil equivalent mdb)	Solar as a Percent of Total
President's Council on Environmental Quality (CEO)	12	50	23%
Walter Morrow	14	79	16%
Stanford Research Institute I** (Business as Usual)	5	73	7%
Stanford Research Institute 2** (Low Solar Cost)	10	70	13%
Stanford Research Institute 3** (High Fuel Cost)	6	45	12%

*Calculations based on quads given in original sources.

**The Stanford Research Institute developed three scenarios. The first is a business-as-usual scenario. The two remaining scenarios are solar-emphasis scenarios. In case 2 the emphasis is achieved by lowered solar costs, whereas in scenario 3 the change comes primarily from increased prices of competing fuels.

Limitations for AFLC

Within the context of achieving energy self-sufficiency for ALCs by the year 2000, most of the individuals who were interviewed for Research Question number 1 believed that solar should be limited primarily to its thermal applications for heating of facilities and providing industrial process heat. Limited use of photovoltaics was advocated for cathodic protection and remote site electrical generation. Photovoltaics, while being able to provide a contribution to the energy requirements was felt to have a minimal impact on the total energy supply for the ALCs.

Thermal solar applications appear to have the greatest potential for contributing substantially to the goal of ALC ESS. Since most of the ALC energy usage is thermal in nature the remainder of this section is primarily devoted to a discussion of solar heating of facilities and processes. While solar cooling systems offer the potential for substantial contributions to the energy picture, they are very expensive and are largely experimental at the present time (31:328). Solar heating projects should have an economic advantage over solar cooling projects within AFLC for the remainder of the decade.

Solar Heating

Solar heating systems are classified as either passive or active. The distinguishing factor of passive systems is that they do not require pumps to circulate liquids through pipes, or fans to circulate air through ducts.

> In passive systems, solar collection and storage subsystems usually are integrated into one component; in fact, in some cases, the whole building functions as a live-in solar collector with built-in storage [94:295].

On the other hand, active solar heating systems circulate liquids or gases through pipes or other conduits to convey the necessary heat to where it can be used, and consists of other components to collect, store and control the energy source. Occasionally, designs incorporate both active and passive systems. These systems are referred to as hybrid (94:297).

Passive Systems

Passive solar designs include direct gain, thermal storage wall, solar greenhouse and roof pond. The direct gain design is the simplest design. It involves large quantities of glass facing south. Collected energy is stored by the floors and walls which constitute the thermal mass. A thermal storage wall usually consists of a massive wall of a dark color which is behind south facing double glazed glass. The wall may be water or masonry and is used to store the energy. A third type of passive system is known as a solar greenhouse. This technique combines direct gain in the greenhouse and a thermal storage wall between the greenhouse and the building. Solar energy provides the heat for the greenhouse and contributes substantially to the heating requirements of the building. A final form of passive solar heating utilizes a roof pond, in which pillows of water act as the collector and thermal storage (94:298).

Active Systems

Active heating systems normally consist of a solar energy collector, which may be flat-plate or concentrating, or both. A storage capacity is necessary to supply energy when the sun is not shining. In addition, an energy distribution system; controls; and an auxiliary energy source are needed to supply energy when the sun is not shining and the energy storage system is depleted.

A typical active solar system is depicted in Figure 14. In the system shown, a portion of the solar energy incident on the solar collector is transferred via a heat transfer medium to the insulated thermal storage tank through the heat exchanger (94:298).

> The heat transfer liquid, which can be a nonfreezing solution or water, is returned to the collector in a closed loop and the process continues. The hot water from the storage tank is used to heat water in the hot water tank and is then returned to storage to be reheated [94:298].

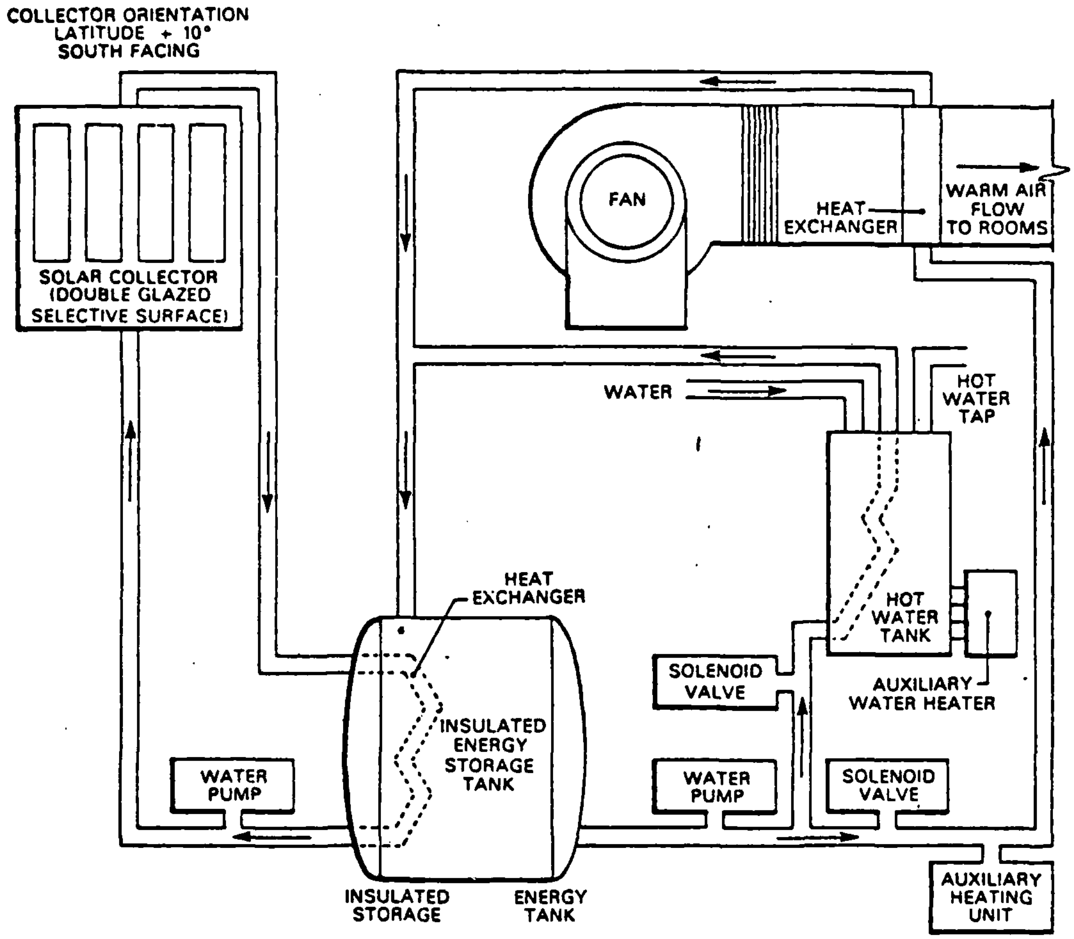


Fig. 14. ACTIVE SOLAR WATER AND SPACE HEATING SYSTEM [94:299]

If the heat has been exhausted from storage, the auxiliary heater warms the water in the hot water tank. To provide space heating, the water from the storage tank is circulated through a water-to-air heat exchanger to warm air which is used in turn for space heating. The water is then returned to the storage tank. If the temperature of the water coming from storage is not adequate enough to heat the building, supplementary heat is provided to the water by the auxiliary heating unit prior to entering the water-to-air exchanger.

Choice for AFLC

At the present time passive solar systems are primarily limited to use in residential construction and the application for AFLC would be minimal. Passive systems could be feasible for administrative facilities; however, this use is outside the scope of this thesis.

Active systems offer the potential for a contribution to a number of AFLC facilities and processes. Each ALC is located in sections of the country which can utilize some form of solar technology.

The DOD has established a goal of supplying 1 percent of the energy needs of DOD facilities with solar and geothermal energy by 1985. "This would mean obtaining the equivalent of up to 2.2 trillion BTU annually from solar energy or approximately 380,000 BOE in fuel savings [95:78]." Although this is a modest saving, integrating solar heating into the Air Force energy system can have significant results since solar energy is an unlimited renewable energy source. "Maintenance and operating expenses are the only cost charged to a solar system during its lifetime [95:78]."

The ALCs seem to be ideal candidates for using solar on a large scale and, thereby, contributing greatly to the DOD goal. Some of the industrial processes involve large tanks with solvents or plating materials which may act as ideal storage mass for the heat received from solar. It may be possible to design solar systems to utilize this process mass rather than having separate hot water or steam storage.

AFLC Solar Initiatives

AFLC has made some progress toward the greater utilization of solar energy. Some of the projects and plans to incorporate solar are provided in the AFLC Master Plan and are listed below (2:51).

ALC	PROJECT
Oklahoma City	Solar Heating of Chemical Plating Tanks
Ogden	Install Solar Heating, Base Swimming Pools
San Antonio	Solar Supplemental Hot Water System, Bldg 61
Sacramento	McClellan Showcase Project
Warner Robins	Solar Heated Water, Corrosion Facility

While these efforts listed are primarily being built to demonstrate the solar technology, they should prove the feasibility for even greater uses of solar.

Solar Section Summary

Solar power has been used by humankind throughout history; however, due to rapidly diminishing supplies of petroleum and increasing energy cost, this energy resource is becoming of greater importance to the country and the Air Force. Solar has many definitions which include thermal applications, fuels from biomass, and solar electric. The immediate future of solar development within AFLC should be in the area of active thermal systems.

While differing opinions exist concerning the contribution possible of nation-wide solar applications, the ALCs seem ideally poised to reap the benefits of solar in its facilities and processes. Current ALC solar projects should prove the feasibility of the technology. The ALCs, because of their high energy usage in facilities and processes, could contribute substantially to the DOD goal of providing 1 percent of facility energy by solar and geothermal by 1985.

Chapter Summary

By analyzing the various waste-to-energy conversion and solar options that are available to the United States Air Force, it may be feasible that some of these techniques may offer the potential for substantially reducing base dependence on outside sources of energy. Even if the contribution to be gained through the use of these systems is small, perhaps their utilization is warranted to make our operations more efficient and less polluting.

Since almost all bases have abandoned landfill areas, perhaps wells can be established in these areas to tap the methane gases produced. This system could conceivably be tied into a refuse pyrolysis system which would also produce gas for productive uses like industrial processes within the Air Force Logistics Command.

Some ALC bases may be able to use Waterwall incinerators to provide at least a portion of their heating requirements. Other bases may be able to generate their own electricity by burning RDF or shredded refuse in fluidized-bed incineration.

It appears that since a major emphasis is being made toward developing coal-fired heating plants, perhaps the potential for using sawdust in these plants is great. This technique would offer a significant contribution for bases located near large forestry operations such as Warner Robins AFB.

It seems feasible that many of our base vehicles or other industrial equipment that operate on diesel fuel could be converted to utilize the waste heat which is generated. A 15 percent reduction in diesel fuel consumption helps amortize the conversions in a relatively short period of time. Perhaps many of the base vehicles or industrial facilities could utilize methane gas produced from the base sewage plant. The sewage plant at Modesto, California handles the sewage from a population similar in size to some of our Air Force and other Department of Defense bases. It is conceivable that the entire base vehicle fleet could be operated on sewage derived fuel or a substantial contribution could be made toward industrial facilities and process thermal requirements.

Perhaps many of our bases could take advantage of their large land areas to produce crops or other plants which could provide energy through biomass conversion. It is conceivable that this process could be coupled with one of the other technologies such as Waterwall incineration or pyrolysis.

Cogeneration through a total energy system appears attractive for the long-term planning aspects of our bases. This one concept would go a long way toward improving base self-sufficiency and energy reliability.

The processes cited above and the others presented in this paper may not be spelled out in any detail in our national energy policy; however, they all have merit in certain situations. The use of RDF at Wright-Patterson AFB is a first step toward exploring some of the other unconventional methods of producing energy. Although RDF has been an uneconomical energy source thus far, within a few years it may be quite attractive. In the meantime the Air Force is learning that it can operate quite well with unconventional energy sources and this may stimulate new ideas to help our energy problems.

AFLC is making strides toward utilizing solar energy at the ALCs. Projects under construction and in the planning phase should demonstrate the potential that is available to reduce outside energy requirements for ALC industrial facilities and processes. Active solar systems should become even more attractive as the price of conventional energy resources continues to rise. The Command should continue to exploit this resource where feasible.

We believe, based on this investigation, that it is feasible from a technological, economical, ecological and a strategical standpoint to expect that substantial quantities of energy will be obtained in future years from waste products and solar energy.

The next and final chapter presents the conclusions and recommendations from this thesis effort. Areas for further study are also considered.

CHAPTER VIII

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This final chapter brings together the efforts of the thesis research. A brief summary of each chapter is provided. Major conclusions drawn from the research questions are discussed and, lastly, recommendations from the total thesis effort are given. Areas for continued or further research are also recommended.

Summary

Chapter I provided the problem statement and objectives to be achieved by this thesis effort. Defining ESS, developing an aggregate statistical forecasting model and providing some recommended energy technology options were stated as the major goals of the research. A systems approach or perspective was presented as a way to view the many factors which affect ESS. This technique was utilized throughout the development of the thesis.

Chapter II provided a general background into the world energy situation with primary emphasis on the United States. The major domestic energy supplies, oil, natural gas, nuclear, coal and hydroelectric were reviewed for their current and potential contribution to the nation's energy demands. Some of the environmental economical, technological and political problems associated with these conventional energy resources were discussed.

Chapter III presented many of the factors affecting the nation's energy policy which in turn have had an impact on DOE, DOD, USAF, and AFLC policy. The concept of "Energy Independence" advocated by Presidents Nixon and Ford was discussed. President Carter's current policies were also presented with an assessment of the impact his policies may have on national self-reliance on domestic energy. The current policies advocated by the DOE, DOD, USAF, and AFLC were also presented in some detail.

Chapter IV presented a discussion of the rationale for energy self-sufficiency. The nation, and the Air Force as well, have become vulnerable to expriencing adverse impacts due to energy shortages. The Air Force has become particularly aware of the impact that petroleum has in its ability to accomplish the mission. Energy shortages, increasing cost, labor disputes in the energy industry and other factors have led Air Force officials to realize that they can exert little other than short-term control over the energy availability for the critical needs under their command.

Chapter V provided an analysis of the interviews conducted to develop the consensus definition of ESS. A separate section was devoted to the ideas and opinions expressed by General Merkling, and finally a definition of ALC ESS was presented.

Chapter VI was devoted to a discussion of various statistical models which were developed to predict the aggregate energy demand for the ALCs. Several variables were utilized to develop the best model.

Chapter VII presented the results of a literature review and interviews concerning alternate energy resources available to the ALCs. The primary focus of the research centered on obtaining energy from waste materials and also solar technologies.

Conclusions

It was concluded that although a wide range of opinions and levels of understanding existed concerning the concept of ESS, the consensus obtained from the energy managers did not differ greatly from the ideas expressed by the AFLC Vice Commander. It was also concluded that ESS for the ALCs as seen by command energy managers involves having the capability for the depots to produce their own energy for a thirty- to sixty-day period. This would be made possible by utilizing stockpiled reserves and/or by using renewable energy sources. Further, the energy requirement would be based upon the needs of the industrial facilities and processes and on an austere level for all other depot activities. Based on this definition, ESS should be an attainable goal by the year 2000.

In fact, ESS could be available within a relatively short period of time by utilizing existing technologies. For example, coal-fired or oil-fired plants could be used along with provisions for adequate supplies of fuels storage. However, it is still not known if ESS is economically feasible. Even if ESS were proven to be economically feasible, it is not known if funds would be made available by Congress for these projects.

The best statistical model developed was based on using heating degree days and cooling degree days as predictor variables. Other variables such as manmonths worked, square footage of floor space and capital investment provided little predictive capability for the various models developed. Future aggregate energy consumption can be accurately predicted by estimating the HDDs and CDDs for the ALCs. This statement is predicated on the underlying assumption that existing patterns of ALC energy consumption do not drastically change. Since energy conservation goals are levied at the aggregate AFLC energy consumption, this model could assist in predicting how well the command may be doing on its overall goal.

A wide variety of alternative energy options are available by utilizing waste to energy conversion technologies and solar energy. Many of these options appear to offer the potential for significant contributions to ALC ESS.

Recommendations

Recommendations for Management Action

One of the primary recommendations of this thesis effort is that the working definition (i.e., a point from which to start planning) of ALC ESS be made available to the energy managers. This is necessary so that they can take action to achieve the ESS objective.

Decisions need to be made concerning the best method of accomplishing the goal. Since the extent of ESS is relatively limited, any consideration that may have been given by ALC energy managers for building large scale coal fired cogeneration or heat plants or other very expensive "single-fix" options may need to be reevaluated.

Some of the technologies presented offer incremental and modular approaches to attaining the goal at less cost and environmental impact than coal-fired plants. Even backup electrical generators could be less costly than building large conventional plants at each depot. Additionally, having coal-fired plants at each installation tends to limit the depot to using only the one technology. Although this may be attractive now, the price of coal could rise as rapidly as petroleum products have in the past. Also, environmental protection groups may place greater pressure on the users of coal to further reduce pollution as alternative energy options become more numerous and if the prices of synfuels begin to ease.

The ALCs are unique when compared to other USAF bases. The ALCs have tremendous thermal requirements; however, they also have large quantities of waste solvents, oils, refuse and other waste products that could feasibly be used to generate energy. Instead of looking at a quick fix for ESS, the individual ALCs need to be evaluated for their own unique mix of energy solutions.

Since ambient temperature is a large determinant of energy consumption for the ALCs, an evaluation needs to be made to determine if functions being performed at one ALC could be performed with less energy at another ALC. Also, consideration should be made to possible consolidation of like processes such as engine test facilities so that waste heat from the processes could be used as an energy source.

The ALCs are extremely energy intensive and more attention needs to be paid to the energy issues. The AFLC Energy Panel has performed a valuable function; however, the members of this panel have primary duties which monopolize the majority of their time. Consideration should be given to establishing a full-time AFLC energy group whose sole function it is to manage energy. The DCS of Engineering and Services has taken steps to establish a Facilities Energy Division. While this is a move in the right direction, a separate operating function or a function developed by using the matrix organization concept may be more appropriate. Savings in energy cost would probably pay for the additional personnel cost incurred many times over.

The ALCs seem ideally situated to take advantage of funds from DOE and also from the use of industrial funds. If the Command decides to take a modular approach to solve its energy dilemma, many energy projects could be justified based upon their savings to the industrial processes.

Recommendations for Future Study

The reader has probably become very aware that many areas for further study could result from the topics covered in this thesis. Rather than developing a list of potential topics, several of special concern are highlighted.

Although this thesis involved developing a statistical model for aggregate forecasting, it may be beneficial to develop individual models for each ALC. This action may provide more information concerning what factors impact the energy consumption of each ALC. In addition, a study needs to be made into forecasting heating and cooling degree days so that the model developed can be accurately utilized. It should also be recognized that the aggregate model should be periodically updated as new data points become available.

Since ESS has been defined in terms of a relatively short period of time and is not intended for operations under the "business as usual" concept, some analysis needs to be done to determine how much less energy the ALCs may need based on the model developed in Research Question number 2. The model predicts based on the "business as usual" scenario and substantial reductions from the baseline should be possible under the ESS surge period. Also, all major organizations and functions at each installation need to be evaluated as to their ability to support ALC operations during "ESS surge periods."

During our research it was apparent that the Navy had made significant strides toward exploring alternative energy technologies and were actively pursuing ESS at many locations. Some of the technologies used at the Naval Public Works Centers and other facilities may have benefits for the Air Force and AFLC. We recommend that a closer working relationship with the Naval energy counterparts be developed and that crossfeed be utilized to aid both services.

APPENDICES

APPENDIX A

TECHNICAL TERMS, ACRONYMS AND CONCEPTS

<u>Air Force Logistics Command</u>: AFLC.

<u>Air Logistics Center</u>: ALC.

<u>Antharacite</u>: A hard, black, lustrous coal that burns efficiently and is therefore valued for its heating quality [31:467].

<u>Barrel</u>: A liquid-volume measure equal to 42 U.S. gallons, commonly used in expressing quantities of petroleum and petroleum products (bbl) [31:467].

<u>Barrel of Oil Equivalent</u>: BOE.

<u>Bituminous coal</u>: Soft coal; coal that is high in carbonaceous and volatile matter. When volatile matter is removed from bituminous coal by heating in the absence of air, the coal becomes coke [31:467].

<u>Breeder</u>: A nuclear reactor that produces more fuel than it consumes. Breeding is possible because of two facts of nuclear physics: (1) Fission of atomic nuclei produces on the average more than two neutrons for each nucleus undergoing reaction. In simplified terms, then, one neutron can be used to sustain the fission chain reaction and the excess neurons can be used to create more fuel. (2) Some nonfissionable nuclei can be converted into fissionable nuclei by capture of a neutron of proper energy. Nonfissionable uranium-238, for example, can thus be bred into fissionable plutonium-239 upon irradiation with high-speed neutrons [31:468].

<u>British thermal unit (Btu)</u>: The quantity of heat necessary to raise the temperature of one pound of water one degree Fahrenheit. One Btu equals 252 calories, 778 foot-pounds, 1055 joules, and 0.293 watt-hours [31:468].

<u>Bulb Turbine</u>: Named for the bulb shaped housing that protects the generator [36:34].

<u>Coal</u>: A solid, combustible organic material formed by the decomposition of vegetable material without free access to air. Chemically, coal is composed chiefly of condensed aromatic ring structures of high molecular weight. It thus has a higher ratio of carbon to hydrogen content than does petroleum [31:468].

Coal gasification: The conversion of coal to a gas suitable for use as a fuel [31:468].

Coal slurry pipelines: A pipeline which transports coal in pulverized form suspended in water [31:468].

Cogeneration systems: See total energy systems.

Crude oil: Petroleum liquids as they come from the ground. Also called simply "crude" [31:468].

Defense Energy Policy Council: DEPC.

Department of Defense: DOD.

Department of Energy: DOE.

Deputy Chief of Staff: DCS.

Diesel oil: The oil fraction left after petroleum and kerosene have been distilled from crude oil [31:469].

Energy: The capacity to do work. A quantity which is conserved, although it may be exchanged among bodies and transformed from one form to another, converted between heat and work, or interconverted with mass [31:469].

Energy conversion: The transformation of energy from one form to another [31:469].

Energy Self-Sufficiency: ESS.

Energy Recovery Research Group: ERRG.

Environmental Protection Agency: EPA.

Fission: The splitting of a heavy nucleus into two approximately equal parts, accompanied by the release of a relatively large amount of energy and generally one or more neutrons. Fission can occur spontaneously, but usually is caused by nuclear absorption of neutrons or other particles [31:470].

Fly ash: The fine, solid particles of noncombustible material residual carried from a bed of solid fuel by the gaseous products of combustion [31:470].

Fossil fuel: Any naturally occurring fuel of an organic nature, such as coal, oil shale, natural gas, or crude oil. Fossil fuels are organically formed from living matter [31:470].

<u>Fuel</u>: A substance used to produce heat energy, chemical energy by combustion or nuclear energy by nuclear fission [31:470].

<u>Fusion</u>: The combining of atomic nuclei of very light elements by collision at high speed to form new and heavier elements, resulting in the release of energy [31:471].

<u>Gallon</u>: A unit of measure. A U.S. gallon contains 231 cubic inches, 0.133 cubic feet, or 3.785 liters. It is 0.83 times the imperial gallon [31:471].

<u>Gas, natural</u>: A naturally occurring mixture of hydrocarbon gases found in porous geologic formations beneath the earth's surface, often in association with petroleum. The principal constituent is methane [31:471].

<u>Gasification</u>: In the most commonly used sense, gasification refers to the conversion of coal to a high-Btu synthetic natural gas under conditions of high temperatures and pressures; in a more general sense, conversion of coal into a usable gas [31:471].

<u>Gasoline</u>: A petroleum fraction composed primarily of small branched-chain, cyclic, and aromatic hydrocarbons [31:471].

<u>Generator (electric)</u>: A machine which converts mechanical energy into electrical energy [31:471].

<u>Geothermal energy</u>: The heat energy available in the rocks, hot water, and steam in the earth's subsurface [31:471].

<u>Heat</u>: A form of kinetic energy, whose effects are produced by the vibration, rotation, and general motions of molecules [31:471].

<u>Heat exchanger</u>: Any device that transfers heat from one fluid (liquid or gas) to another or to the environment [31:472].

<u>Hydrocarbon</u>: A compound containing only carbon and hydrogen. The fossil fuels are predominantly hydrocarbons, with varying amounts of organic compounds of sulfur, nitrogen, and oxygen, and some inorganic materials [31:472].

<u>Hydroelectric plant</u>: An electric power plant in which energy of falling water is converted into electricity by turning a turbine generator [31:472].

Insolation: The amount of solar radiation per unit of horizontal surface over a period of time [31:316].

Kerosene: The petroleum fraction containing hydrocarbons that are slightly heavier than those found in gasoline and naphtha [31:472].

Kilowatt (kW): 1,000 watts. A unit of power equal to 1,000 watts or to energy consumption at a rate of 1,000 joules per second. It is usually used for electrical power. An electric motor rated at one horsepower uses electrical energy at a rate of about 3/4 kilowatt [31:472].

Kilowatt-hour (kWh): A unit of work or energy equal to one kilowatt in one hour. It is equivalent to 3.6 M joules [31:472].

Landfill methane gas: LMG.

Lignite: A low-grade coal of a variety intermediate between peat and bituminous coal [31:472].

Liquefaction (of coal): The conversion of coal into liquid hydrocarbons and related compounds by hydrogenation [31:473].

Megawatt (MW): 1,000 kilowatts, 1 million watts [31:473].

Methane (CH_4). The lightest in the paraffinic series of hydrocarbons. It is colorless, odorless and flammable. It forms the major portion of marsh gas and natural gas [31:473].

Million cubic feet: MCF.

National Environmental Policy Act (NEPA): An act passed in 1970 requiring that the environmental impact of most large projects and programs be considered. Among its important provisions is one requiring a detailed statement of environmental impact of and alternatives to a project to be submitted to the government before the project can begin [31:474].

Natural gas: Naturally occurring mixtures of hydrocarbon gases and vapors, the more important of which are methane, ethane, propane, butane, pentane, and hexane. The energy content of natural gas is usually taken as 1032 Btu/cu ft [31:474].

Net reserves: The recoverable quantity of an energy resource that can be produced and delivered [31:474].

Nuclear fission: The splitting of large atomic nuclei into two or more new nuclear species, with the release of large amounts of energy [31:474].

Nuclear fusion: The process by which small atomic nuclei join together with the release of large amounts of energy [31:474].

Nuclear power plant: Any device, machine, or assembly that converts fission nuclear energy into some form of useful power, such as electrical power [31:474].

Nuclear reactor: A device in which a fission chain reaction can be initiated, maintained, and controlled. Its essential component is a core with fissionable fuel. It usually has a moderator, reflector, shielding, coolant, and control mechanisms. It is the basic machine of nuclear power [31:474].

Organization of Petroleum Exporting Countries (OPEC). Founded in 1960 to unify and coordinate petroleum policies of the members. The members and the date of membership are: Abu Dhabi (1967); Algeria (1969); Indonesia (1962); Iran (1960); Iraq (1960); Kuwait (1960); Libya (1962); Nigeria (1971); Qatar (1961); Saudi Arabia (1960); and Venezuela (1960). OPEC headquarters are in Vienna, Austria [31:474].

Particulate matter: Solid particles, such as the ash, which are released from combustion processes in exhaust gases at fossil-fuel plants [31:475].

Petroleum: An oily flammable bituminous liquid that may vary from almost colorless to black, occurs in many places in the upper strata of the earth, is a complex mixture of hydrocarbons with small amounts of other substances, and is prepared for use as gasoline, naphtha, or other products by various refining processes [31:475].

Photovoltaic conversion: Transformation of solar radiation directly into electricity by means of a solid-state device such as the single-crystal silicon solar cell [31:475].

Planning, Programming Review Board: PPRB.

Pollution: The accumulation of wastes or byproducts of human activity. Pollution occurs when wastes are discharged in excess of the rate at which they can be degraded, assimilated, or dispersed by natural processes. Sometimes noxious environmental effects not caused by human activity are also called pollution [31:475].

Polyvinal chloride: PVC.

Power: The rate at which work is done or energy is transformed. Power is measured in units of work per unit time; typical units are the horsepower and the watt [31:475].

Proved reserves: The estimated quantity of crude oil, natural gas, natural gas liquids, or coal, which analysis or geological and engineering data demonstrates with reasonable certainty to be recoverable from known oil, coal, or gas fields under existing economic and operating conditions [31:476].

Quad: Quadrillion Btus = 10^{15} Btu (31:8).

Radioactivity. The spontaneous decomposition of an atom accompanied by the release of energy [31:476].

Real property installed equipment: RPIE.

Refuse derived fuel: RDF.

Secondary recovery: Oil and gas obtained by the augmentation of reservoir energy: often by the injection of air, gas, or water into a production formation [31:476].

Solar cell: A device which converts solar radiation to a current of electricity [31:476].

Steam power plant: A plant in which the prime movers (turbines) connected to the generators are driven by steam [31:477].

Tertiary recovery: Use of heat and other methods other than fluid injection to augment oil recovery (presumably occurring after secondary recovery) [31:477].

Thermal pollution: An increase in the temperature of water resulting from waste heat released by a thermal electric plant, for example, added to the cooling water [31:477].

Ton: A unit of weight equal to 2,000 pounds in the United States, Canada, and the Union of South Africa, and to 2,240 pounds in Great Britain. The American ton is often called the short ton, while the British ton is called the long ton. The metric ton, of 1,000 kilograms equals 2,204.62 pounds [31:477-478].

Total energy systems: Combined processing plants that generate electricity; use residual and recycled energy for heating, air conditioning, and hot water; treat water; process solid wastes, and treat liquid wastes. These systems are often called cogeneration systems [31:388].

Trillion cubic feet: TCF.

Turbine: An engine, the shaft of which is rotated by a stream of water, stream, air, or fluid from a nozzle forced against blades of a wheel [31:478].

Waste heat: Heat which is at temperatures very close to the ambient and hence is not valuable for production of power and is discharged to the environment [31:478].

Wastes, radioactive: Equipment and materials, from nuclear operations, which are radioactive and for which there is no further use. Wastes are generally classified as high-level (having radioactivity concentrations of hundreds to thousands of curies per gallon or cubic foot), low-level (in the range of 1 microcurie per gallon or cubic foot), or intermediate [31:478].

Watt: A Unit of power. It is the rate of energy use or conversion when one joule of energy is used or converted per second. (A joule is about 0.25 calories.) [31:478].

APPENDIX B

EXECUTIVE ORDER 12003, JULY 20, 1977
RELATING TO ENERGY POLICY
AND CONSERVATION

By virtue of the authority vested in me by the Constitution and the statutes of the United States of America, including the Energy Policy and Conservation Act (89 Stat. 871, 32 U.S.C. 6201 et seq.), the Motor Vehicle Information and Cost Savings Act, as amended (15 U.S.C. 1901 et seq.), Section 205(a) of the Federal Property and Administrative Services Act of 1949, as amended (40 U.S.C. 486(a)), and Section 301 of Title 3 of the United States Code, and as President of the United States of America, it is hereby ordered as follows:

SECTION 2. Section 1 of Executive Order No. 11912 of April 13, 1976, is amended to read as follows:

"Section 1. (a) The Administrator of General Services is designated and empowered to perform, without approval, ratification or other action by the President, the function vested in the President by Section 510 of the Motor Vehicle Information and Cost Savings Act, as amended (89 Stat. 915, 15 U.S.C. 2010). In performing this function, the Administrator of General Services shall:

(1) Promulgate rules which will ensure that the minimum statutory requirement for fleet average fuel economy is exceeded (i) for fiscal year 1978 by 2 miles

per gallon, (ii) for fiscal year 1979 by 3 miles per gallon, and (iii) for fiscal years 1980 and after by 4 miles per gallon.

(2) Promulgate rules which will ensure that Executive agencies do not acquire subsequent to fiscal year 1977, any passenger automobile unless such automobile meets or exceeds the average fuel economy standard for the appropriate model year established by, or pursuant to, Section 502(a) of the Motor Vehicle Information and Cost Savings Act, as amended (15 U.S.C. 2002(a)); except that, such rules (i) shall not apply to automobiles designed to perform combat-related missions for the Armed Forces or designed to be used in law enforcement work or emergency rescue work, and (ii) may provide for granting exemptions for individual automobiles used for special purposes as determined to be appropriate by the Administrator of General Services with the concurrence of the Administrator of the Federal Energy Administration.

"(b). The Administrator of General Services shall promulgate rules which will ensure that each class of non-passenger automobiles acquired by all Executive agencies in each fiscal year, beginning with fiscal year 1979, achieve for such fiscal year a fleet average fuel economy not less than the average fuel economy standard for such class, established pursuant to Section 502(b) of the Motor Vehicle Information and Cost Savings Act, as amended (89 Stat. 903, 15 U.S.C. 2002(b)), for the model year which includes January 1 of such fiscal year; except that, such rules (1) shall not apply to automobiles designed to perform combat-related missions for the Armed Forces or designed to be used in law enforcement work or emergency rescue work, and (2) may provide for granting exceptions for other categories of automobiles used for special purposes as determined to be appropriate by the Administrator of General Services with the concurrence of the Administrator of the Federal Energy Administration."

SEC. 2. Executive Order No. 11912 of April 13, 1976, is further amended by adding the following new section:

"Sec. 10.(a) (1) The Administrator of the Federal Energy Administration, hereinafter referred to as the Administrator, shall develop, with the concurrence of the Director of the Office of Management and Budget, and in consultation with the Secretary of Defense, the Secretary of Housing and Urban Development, the Administrator of Veterans' Affairs, the Administrator of the Energy Research and Development Administration, the Administrator of General Services, and the heads of such other Executive agencies as he deems appropriate, the ten-year plan for energy conservation with respect to Government buildings, as provided by Section 381(a)(2) of the Energy Policy and Conservation Act (42 U.S.C. 6361 (a)(2)).

2. The goals established in subsection (b) shall apply to the following categories of Federally-owned buildings: (i) office buildings, (ii) hospitals, (iii) schools, (iv) prison facilities, (v) multi-family dwellings, (vi) storage facilities, and (vii) such other categories of buildings for which the Administrator determines the establishment of energy-efficiency performance goals is feasible.

"(b) The Administrator shall establish requirements and procedures, which shall be observed by each agency unless a waiver is granted by the Administrator, designed to ensure that each agency to the maximum extend practicable aims to achieve the following goals:

(1) For the total of all Federally-owned existing buildings the goal shall be a reduction of 20 percent in the average annual energy use per gross square foot of floor area in 1985 from the average energy use per gross square foot of floor area in 1975. This goal shall apply to all buildings for which construction was or design specifications were completed prior to the date of

promulgation of the guidelines pursuant to subsection (d) of this Section.

(2) For the total of all Federally-owned new buildings the goal shall be a reduction of 45 percent in the average annual energy requirement per gross square foot of floor area in 1985 from the average annual energy use per gross square foot of floor area in 1975. This goal shall apply to all new buildings for which design specifications are completed after the date of promulgation of the guidelines pursuant to subsection (d) of this Section.

"(c) The Administrator with the concurrence of the Director of the Office of Management and Budget, in consultation with the heads of the Executive agencies specified in subsection (a) and the Director of the National Bureau of Standards shall establish, for purposes of developing the ten-year plan, a practical and effective method for estimating and comparing life cycle capital and operating costs for Federal buildings, including residential, commercial, and industrial type categories. Such methods shall be consistent with the Office of Management and Budget Circular No. A-94, and shall be adopted and used by all agencies in developing their plans pursuant to subsection (e), annual reports pursuant to subsection (g), and budget estimates pursuant to subsection (h). For purposes of this paragraph, the term "life cycle cost" means the total costs of owning, operating, and maintaining a building over its economic life, including its fuel and energy costs, determined on the basis of a systematic evaluation and comparison of alternative building systems.

"(d) Not later than November 1, 1977, the Administrator, with the concurrence of the Director of the Office of Management and Budget, and after consultation with the Administator of General Services and the heads of the Executive agencies specified in subsection (a) shall issue guidelines for the plans to be submitted pursuant to subsection (e).

"(e) (1) The head of each Executive agency that maintains any existing building or will maintain any new building shall submit no later than six months after the issuance of guidelines pursuant to subsection (d), to the Administrator a ten-year plan designed to the maximum extent practicable to meet the goals in subsection (b) for the total of existing or new Federal buildings. Such ten-year plans shall only consider improvements that are cost-effective consistent with the criteria established by the Director of the Office of Management and Budget (OMB Circular A-94) and the method established pursuant to subsection (c) of this Section. The plan submitted shall specify appropriate energy-saving initiatives and shall estimate the expected improvements by fiscal year in terms of specific accomplishments--energy savings and cost savings--together with the estimated costs of achieving the savings.

(2) The plans submitted shall, to the maximum extent practicable, include the results of preliminary energy audits of all existing buildings with over 30,000 gross square feet of space owned and maintained by Executive agencies. Further, the second annual report submitted under subsection (g) (2) of this Section shall, to the maximum extent practicable, include the results of preliminary energy audits of all existing buildings with more than 5,000 but not more than 30,000 gross square feet of space. The purpose of such preliminary energy audits shall be to identify the type, size, energy use level and major energy using systems of existing Federal buildings.

(3) The Administrator shall evaluate agency plans relative to the guidelines established pursuant to subsection (d) for such plans and relative to the cost estimating method established pursuant to subsection (c). Plans determined to be deficient by the Administrator will be returned to the submitting agency head for revision and resubmission within 60 days.

(4) The head of any Executive agency submitting a plan, should he disagree with the Administrator's determination with respect to that plan, may appeal to the Director of the Office of Management and Budget for resolution of the disagreement.

"(f) The head of each agency submitting a plan or revised plan determined not deficient by the Administrator, or on appeal, by the Director of the Office of Management and Budget, shall implement the plan in accord with approval budget estimates.

"(g) (1) Each Executive agency shall submit to the Administrator an overall plan for conserving fuel and energy in all operations of the agency. This overall plan shall be in addition to and include any ten-year plan for energy conservation in Government buildings submitted in accord with Subsection (e).

(2) By July 1 of each year, each Executive agency shall submit a report to the Administrator on progress made toward achieving the goals established in the overall plan required by paragraph (1) of this subsection. The annual report shall include quantitative measures and accomplishments with respect to energy saving actions taken, the cost

of these actions, the energy saved, the costs saved, and other benefits realized.

(3) The Administrator shall prepare a consolidated annual report on Federal government progress toward achieving the goals, including aggregate quantitative measure of accomplishment as well as suggested revisions to the ten-year plan, and submit the report to the President by August 15 of each year.

"(h) Each agency required to submit a plan shall submit to the Director of the Office of Management and Budget with the agency's annual budget submission, and in accordance with procedures and requirements that the Director shall establish, estimates for implementation of the agency's plan. The Director of the Office of Management and Budget shall consult with the Administrator about the agency budget estimates.

"(i) Each agency shall program its proposed energy conservation improvements of buildings so as to give the highest priority to the most cost-effective projects.

"(j) No agency of the Federal government may enter into a lease or a commitment to lease a building and construction of which has not commenced by the effective date of this Order unless the building will likely meet or exceed the general goal set forth in subsection (b)(2).

"(k) The provisions of this Section do not apply to housing units repossessed by the Federal Government."

APPENDIX C*

AIR FORCE LOGISTICS COMMAND

*From Air Force Logistics Command, Wright-Patterson AFB, Ohio, Office of Public Affairs.

The mission of Air Force Logistics Command (AFLC) is to keep the U.S. Air Force's aerospace weapon systems in a constant state of combat readiness--world-wide. In carrying out this mission, AFLC provides the logistics management needed to keep the Air Force's aircraft, missiles and support equipment in top condition. The command also supports all Air National Guard and U.S. Air Force Reserve activities, air forces of friendly nations receiving U.S. military assistance, and other U.S. government agencies.

AFLC has its headquarters at Wright-Patterson AFB, Ohio. Its four main logistics functions are procurement, supply, transportation, and maintenance. These and other command responsibilities are divided among five air logistics centers and seven specialized organizations. Through these units AFLC provides a worldwide direct logistics support system--wholesales to consumer.

The command's direct support of aircraft and missiles means high-speed movement of priority materials to any Air Force activity in the world.

The command's installations and units:

Ogden Air Logistics Center (ALC), Hill AFB, Utah.

Oklahoma City ALC, Tinker AFB, Okla.

San Antonio ALC, Kelly AFB, Tex.

Sacramento ALC, McClellan AFB, Calif.

Warner Robins ALC, Robins AFB, Ga.

Air Force Acquisition Logistics Division, Wright-Patterson AFB, Ohio.

Aerospace Guidance and Metrology Center, Newark AFS, Ohio.

Air Force Contract Maintenance Center, Wright-Patterson AFB, Ohio.

Military Aircraft Storage and Disposition Center, Davis-Monthan AFB, Ariz.

2750th Air Base Wing, Wright-Patterson AFB, Ohio.

Air Force Museum, Wright-Patterson AFB, Ohio.

International Logistics Center, Wright-Patterson AFB, Ohio.

SIZE OF AFLC
(End FY 1979)

<u>Personnel Assigned</u>

Civilian	79,785
Officer	2,499
Enlisted	7,058
Total	89,342

<u>Assets</u>

Capital Assets	$67.3 billion
Sales (stock & Industrial funds).	$5.66 billion

<u>Materiel Management</u>

Total Items Managed	879,292
Gross Requisitions Received . . .	4,756,320
Basic Technical Orders & Time Compliance TOs	98,144

Procurement

Central Procurement Actions	187,909
Base Procurement Actions	476,434
Small Business Awards	$803 million
Total Procurement Obligation Dollars	6.0 billion

Transportation

Material Receipts Processed:

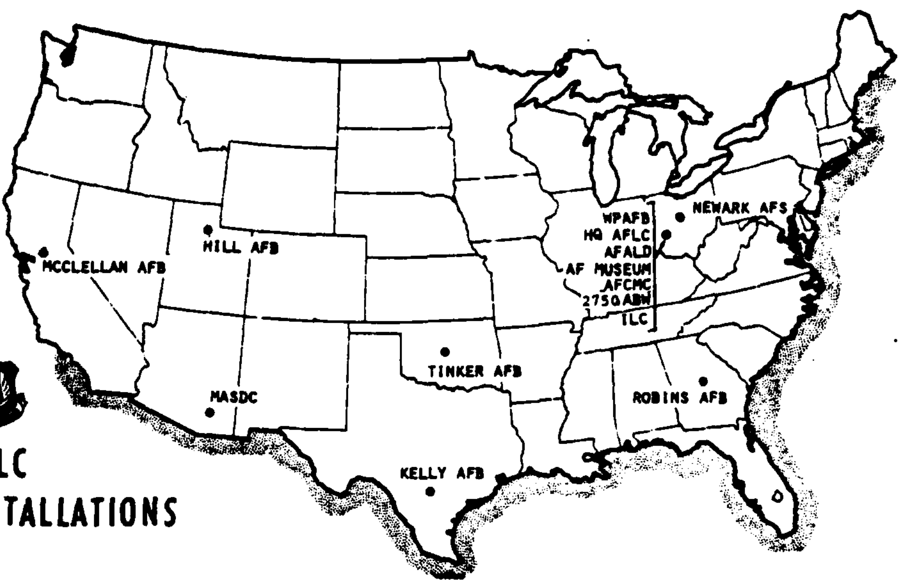
Posted	3.2 million
Binned	2.6 million

Logistics Airlift (LOGAIR):

Miles Flown	10.9 million
Tons Moved	111.9 thousand
Cost of Operations	$41.0 million

Maintenance

USAF Active Aircraft Inventory . . .	6,965
Depot Maintenance Actions	1,982



AFLC INSTALLATIONS

OGDEN AIR LOGISTICS CENTER
HILL AFB, UTAH

Ogden ALC provides worldwide logistics support for the entire Air Force fleet of intercontinental ballistic missiles (ICBMs), as well as the F-16, F/RF-4, and F/RF-101 aircraft. Additional responsibilities include management of the Bomarc drone missile; the Maverick air-to-ground missile; GBU-15 guided bombs; the Emergency Rocket Communication System. The MX missile is Ogden ALC's latest assignment.

Ogden is the logistics manager for all air-munitions, solid propellants and explosive devices used throughout the Air Force. All varieties of munitions, propellants, and explosive components (except nuclear), as well as the latest and most powerful ICBM motors, are tested at a range located 48 air miles west of the base.

Other worldwide responsibilities include management of aircraft landing gears; wheels, brakes, struts, tires, and tubes for all types of aircraft; all photographic and reconnaissance equipment; and aerospace training equipment for all weapon systems.

Ogden is the worldwide materiel manager for:

<u>Aircraft</u>

F/RF-4

F/RF-101

F-16

Missiles

LGM-30 Minuteman

LGM-25C Titan II

CIM-10 Bomarc

AGM-65 Maverick

GBU-15 Laser Guided Bomb

As Utah's largest employer, Hill AFB has 14,000 civilian and 5,000 military people. Its annual payroll exceeds $331 million. The base is located 25 miles north of Salt Lake City and 10 miles south of Ogden. The installation covers 7,000 acres.

SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AFB, CALIFORNIA

The mission performed by the Sacramento ALC is twofold. First, it has worldwide logistic management responsibilities for assigned weapon systems, equipment, and commodity items. Second, it also performs an industrial type service essential to Air Force logistics.

Sacramento ALC serves as System Manager for a number of aircraft including the F-111, FB-111, F-105, F-100, F-104, T-33, T-39, A-10, C-12, C-121, F-86, and the F-84. It is also system manager for the Space Support Programs; Defense Support Program; GM16/LV3, Atlas Booster Program; AF Satellite Communications System; Space Transportation

System (Space Shuttle); Drone Tracking Control System, and Defense MET Satellite Program.

Sacramento is item manager for ground radar units, airframe components, ground communication components and all airborne and ground generators. It manages a total of 122,000 items of which 40,000 are aircraft related, 56,000 are communications-electronics-meteorological (CEM) related, and 26,000 are space/commodity related.

In the Maintenance area, Sacramento ALC is responsible for the repair and modification of F/FB-111, A-10, and F-16 aircraft. The ALC is also assigned as the Technology Repair Center for hydraulics, flight control accessories, electrical components, and ground communications and electronics components.

In fulfilling its central procurement mission, the ALC contracts for materiel and services needed for support of its assigned weapon systems and commodity classes. In the base procurement area, the ALC serves as purchasing agent for activities at McClellan AFB--both Sacramento ALC and tenant organizations.

McClellan AFB is home for 30 tenant organizations including the U.S. Coast Guard Station, Sacramento.

McClellan AFB employs approximately 13,200 civilians and 3,400 military personnel. Its annual payroll is approximately $316.5 million. Located nine miles northeast of Sacramento, the 2,583 acre installation was completed in April 1939. It was named for Major Hezekiah McClellan, a pioneer in charting Alaskan air routes in the early 1930s.

OKLAHOMA CITY AIR LOGISTICS CENTER
TINKER AFB, OKLAHOMA

Oklahoma City ALC provides worldwide logistics support for a variety of weapon systems, including A-7D, B-52, multi-purpose-135 series aircraft, E-3A and E-4 aircraft, and the SRAM and Air Launched Cruise (ALCM) missiles. The Center also manages a large family of aircraft engines including the TF-30, TF-41, TF-33 and J-79.

Oklahoma City is the exclusive Air Force Technology Repair Center for hydraulic/pneudraulics transmissions, air-driven accessories, oxygen components, engine instruments, and automatic flight control instruments. It is also the only inland aerial port of embarkation in the United States.

The Center manages the Maintenance Analysis and Structural Integrity Information System. Involved are recording systems for malfunction detection analysis on the C-5 and information on structural integrity management for several other aircraft. Data collected from recording equipment on the aircraft are analyzed to identify malfunctions and to develop life cycle forecasts and other predictive information.

Oklahoma City also provides central management of the worldwide Technical Order Distribution System. It assigns all Air Force Technical Order numbers; compiles, prints and keeps current numerical indexes of all active orders; and distributes them worldwide.

Oklahoma City ALC is the System Manager for:

<u>Aircraft</u>

A-7	KC-135	E-4
B-52	VC-137	
C-97	E-3A	

<u>Missiles</u>

AGM-69 SRAM

AGM-86A ALCM

ADM-20 Quail

AGM-28 Hound Dog

<u>Engines</u>

F-101	J-75	T-64
J-33	J-79	TF-30
J-47	T-58	TF-33
J-57		TF-41

As the largest single industrial employer in Oklahoma, Tinker AFB employs about 16,200 civilian and 5,500 military people. Its annual payroll is about $391 million. The base is located in extreme southeast Oklahoma City and covers more than 4,300 acres.

SAN ANTONIO AIR LOGISTICS CENTER
KELLY AFB, TEXAS

San Antonio ALC provides worldwide logistics support for 16 different weapon systems such as the C-5, F-5, the F-5E (International Fighter), F-106, and T-38 aircraft. It also manages 23,500 aircraft engines and more than 51,000 non-aircraft engines (more than half of the Air Force engine inventory).

Additional major responsibilities include equipment for life support, automatic test, precision measuring and support equipment.

Unique San Antonio ALC responsibilities include those for the Air Force's nuclear ordnance, all of the fuels and lubricants used by the Air Force and the National Aeronautics and Space Administration, the Air Force's fleet of boats and ships and the Department of Defense Working Dog Program.

The Center also has a unit involved in the deployment of the F-5E International Fighter and other support responsibilities in Europe and the Middle East.

As a specialized repair activity, San Antonio modernized and performed heavy depot maintenance on 45 C-5s, 24 F-101s, 53 B-52s and 16 OV-10s in Fiscal Year 1979. It is the exclusive Air Force Technology Repair Center for electronic aerospace ground equipment, electromechanical support equipment and nuclear components; and is one of the two repair centers for engine components (Oklahoma City ALC is the other).

San Antonio is the System Manager for:

A-37	F-5	T-29
C-5	F-51	T-37
C-6	F-102	T-38
C-9	F-106	T-41
C-131	O-2	T-43
	OV-10	

Kelly AFB employs about 17,500 civilians and approximately 4,500 military people. Its annual payroll exceeds $360 million. The installation is located on the southwest side of San Antonio and covers an area of 4,500 acres.

WARNER ROBINS AIR LOGISTICS CENTER
ROBINS AFB, GEORGIA

Warner Robins ALC provides worldwide logistics support for a broad spectrum of weapon systems including the C-141, C-130, C-119 and C-123 transports; the F-15 fighter; the reconnaissance-configured B-57 bomber; H-3 and H-53 helicopters; U-10 and U-16 utility aircraft; and AIM-7, AIM-9, AGM-45 and A/BQM-34 missiles. The Center also manages equipment for fire control, bomb navigation, airborne communication, airborne radar and electronic warfare.

Other responsibilities include the management of vehicles; propellers; airborne guns; hand weapons; general purpose automatic data processing equipment; and bearings.

The F-15, C-141 and C-130 aircraft are overhauled at Warner Robins, but the majority of the Center's maintenance effort involves the repair of equipment. It is the Technology Repair Center for airborne electronics, gyros, propellers, and life support equipment.

Warner Robins ALC is the System Manager for:

<u>Aircraft</u>

B-57	C-140	U-4
C-7	C-141	U-6
C-47	F-15	U-10
C-54	H-1	U-16
C-118	H-3	U-17
C-119	H-43	U-18B
C-123	H-53	
C-130	U-3	

<u>Missiles</u>

AIM-4	AGM-45	A/BQM-34
AIM-7	AGM-78	AQM-81A
AIM-9	AGM-88	

Robins AFB employs more than 15,000 civilian and 4,000 military people. Its annual payroll is more than

$322 million. The base is located adjacent to the city of Warner Robins, 18 miles south of Macon, and covers an area of 7,625 acres.

APPENDIX D

AFLC ENERGY SELF-SUFFICIENCY INTERVIEW GUIDE

Introduction

We are writing a thesis concerning energy self-sufficiency at AFLC Air Logistics Centers as part of the graduation requirements for a Master's Degree at AFIT's School of Systems and Logistics. While energy self-sufficiency is a stated goal in the AFLC Energy Plan, no operational definition has yet been developed to begin working toward this goal. As part of our thesis we wish to develop, by concensus from those in AFLC who are involved in achieving this goal, an operational definition for energy self-sufficiency in AFLC.

Would you comment on some questions concerning energy self-sufficiency?

1. Do you think energy self-sufficiency is a reasonable and attainable goal by 2000 A.D.? Yes ______ No ______ Depends ______

   A. (If Yes) What do you think is a realistic definition of energy self-sufficiency for AFLC? ________________________________

   ____

   ____

   ____

   B. (If No) Why not? ________________________________

   ____

   ____

   ____

   ____

2. What scope of energy self-sufficiency do you believe should be attempted?

   ______No dependence on outside sources? ______Own energy resources? ______Stockpile resources?

   ______Vertical? ______Horizontal?

   Other? ____

   ____

3. What time period of energy self-sufficiency do you believe should be attempted?

_____Indefinite? _____At least one year? _____12-6 mos?

_____6-3 mos? _____60-30 days?

Other? ______________________________

4. What extent of energy self-sufficiency do you believe AFLC should attempt?

_____Total base functions? _____All industrial facilities?

_____Some priority system? _____Some minimum based on war or emergency essential?

Other? ______________________________

____

5. What methods or techniques should AFLC use to obtain energy self-sufficiency?

_____Cogeneration? _____Solar? _____Geothermal?

_____Biomass? _____RDF? _____Coal?

_____Nuclear? _____Total energy system?

Other? ______________________________

6. Do you think AFLC should concentrate on energy self-sufficiency or rather more energy efficient facilities and processes?

____

____

7. Would you favor a Defense Utility to provide the energy requirements for DOD facilities and installations rather than individual base self-sufficiency?

____

____

____

8. Do you have other comments? ______________________________

____

____

____

____

APPENDIX E

DATA BASE

JDAT		ENERGY	MMTHS	SQFT	CAPINV	HHD	CDD
5304	01	1269154	76140.87	58274514	0888718	0662	0466
5334	02	1504317	75993.57	58274514	0888718	2128	0079
5365	03	1691148	75747.20	58274514	0908596	3278	0005
6031	04	1810669	75341.12	58274514	0908596	3690	0026
6060	05	1608809	74759.13	58274514	0908596	2424	0004
6091	06	1461697	74130.77	58274514	0908596	2160	0093
6121	07	1294037	73442.23	58274514	0908596	1153	0241
6152	08	1069247	72120.03	58274514	0908596	0388	0657
6182	09	1116389	70951.54	60542405	0951649	0106	1406
6213	10	1164743	71410.05	60542405	0951649	0000	2166
6244	11	1205211	71094.86	60542405	0951649	0006	2005
6274	12	1166868	70723.50	60542405	0951649	0076	1236
6305	13	1205175	71614.31	60503258	0951649	1028	0225
6335	14	1568010	71270.06	60503258	0951649	2222	0010
6366	15	1776877	71189.90	60503258	0951649	3406	0000
7031	16	1782676	71122.20	60503258	0951649	4235	0000
7059	17	1531888	71119.99	60503258	0951649	2459	0004
7090	18	1427151	71258.00	60723445	0965877	3777	0079
7120	19	1169989	70873.22	60723445	0965877	0661	0273
7151	20	1161711	71030.35	60723445	0965877	0608	0840
7181	21	1186009	71384.80	60723445	0965877	0009	1916
7212	22	1207436	71074.44	60723445	0965877	0000	2371
7243	23	1285786	70654.12	60723445	0965877	0021	2163
7273	24	1210281	70986.24	60618575	0982658	0116	1563
7304	25	1126707	70527.61	60618575	0982658	0642	0333
7334	26	1409995	70709.06	60618575	0982658	1783	0048
7365	27	1642904	70738.60	60618575	0982658	3026	0004
8031	28	1841489	70423.63	60618575	0982658	4007	0002
8059	29	1766237	70740.91	60618575	0982658	3296	0006
8090	30	1496746	70847.78	61953021	1016625	1945	0041
8120	31	1188527	70725.81	61953021	1016625	0968	0327
8151	32	1218550	70660.09	61953021	1016625	0417	0971
8181	33	1235513	70891.04	61953021	1016625	0070	1673
8212	34	1259181	70892.91	61953021	1016625	0002	2223
8243	35	1328498	70723.91	61953021	1016625	0026	2087
8273	36	1223494	70538.11	62054140	1040213	0197	1414
8304	37	1243997	70136.94	62054140	1040213	0512	0393
8334	38	1441787	70177.43	62054140	1040213	1978	0119
8365	39	1717846	69994.39	62054140	1040213	3493	0021
9031	40	1997256	69630.06	62054140	1040213	4403	0001
9059	41	1788681	69431.50	62054140	1041213	3151	0010
9090	42	1489902	69393.36	62459516	1054985	1833	0084
9120	43	1245496	69259.83	62459516	1054985	1047	0237
9151	44	1096370	69052.25	62459516	1054985	0424	0770
9181	45	1121699	69175.20	62459516	1054985	0107	1444
9212	46	1241020	68633.72	62459516	1054985	0000	1830
9243	47	1265405	68430.15	62459516	1054985	0001	2054
9273	48	1144218	68433.34	62893790	1117341	0047	1317

JDAT = JULIAN DATE, E.G. 5304 = OCTOBER 1975
MMTHS = MAN-MONTHS WORKED PER MONTH
SQFT = SQUARE FOOTAGE OF FLOOR SPACE
CAPINV = CAPITAL INVESTMENT
HHD = HEATING DEGREE DAYS
CDD = COOLING DEGREE DAYS

Master Data Base

JDAT	OO-ALC	OC-ALC	SM-ALC	SA-ALC	WR-ALC	TOTAL
5304	289402.0	326506.0	178733.0	226609.0	247904.0	1269154.0
5334	384611.0	374033.0	244494.0	235974.0	265205.0	1504317.0
5365	426005.0	428164.0	280470.0	255066.0	301443.0	1691148.0
6031	413505.0	471589.0	273958.0	291697.0	359920.0	1810669.0
6060	414203.0	423300.0	240395.0	231639.0	299272.0	1608809.0
6091	414882.0	341170.0	219982.0	258511.0	227152.0	1461697.0
6121	337851.0	354644.0	203981.0	220681.0	176880.0	1294037.0
6152	212598.0	282948.0	169935.0	218157.0	185789.0	1069427.0
6182	179541.0	325932.0	158164.0	233369.0	219383.0	1116389.0
6213	191672.0	342495.0	171337.0	228943.0	230296.0	1164743.0
6244	191100.0	357860.0	171632.0	247878.0	236741.0	1205211.0
6274	180677.0	351106.0	170759.0	227975.0	236351.0	1166868.0
6305	282206.0	318052.0	170994.0	203686.0	230237.0	1205175.0
6335	365529.0	420165.0	219043.0	264342.0	298931.0	1568010.0
6366	456457.0	439538.0	257831.0	275974.0	347077.0	1776877.0
7031	361955.0	492650.0	243484.0	315509.0	369078.0	1782676.0
7059	345423.0	463294.0	194183.0	231464.0	297524.0	1531888.0
7090	421269.0	373443.0	168700.0	232661.0	231078.0	1427[illegible].0
7120	305997.0	306802.0	175900.0	206020.0	175270.0	1169989.0
7151	256142.0	314405.0	182971.0	223125.0	185068.0	1161711.0
7181	184905.0	367729.0	161886.0	249471.0	222018.0	1186009.0
7212	178828.0	376868.0	171663.0	239030.0	241047.0	1207436.0
7243	200413.0	378888.0	162038.0	279156.0	265291.0	1285786.0
7273	192413.0	381347.0	155666.0	243487.0	237368.0	1210281.0
7304	252436.0	305320.0	157483.0	213908.0	197560.0	1126707.0
7334	378482.0	374071.0	216311.0	211068.0	230063.0	1409995.0
7365	439420.0	398021.0	237649.0	240988.0	326826.0	1642904.0
8031	467973.0	441620.0	248424.0	312879.0	370593.0	1841489.0
8059	421489.0	514117.0	204481.0	287363.0	338787.0	1766237.0
8090	388696.0	404687.0	179117.0	252871.0	271375.0	1496746.0
8120	328177.0	292956.0	186089.0	197071.0	184234.0	1188527.0
8151	264500.0	315833.0	176193.0	254101.0	207923.0	1218550.0
8181	204804.0	337588.0	174816.0	267028.0	251277.0	1235513.0
8212	198128.0	371162.0	174996.0	262685.0	252210.0	1259181.0
8243	204684.0	414157.0	169625.0	278177.0	261855.0	1328498.0
8273	225783.0	341242.0	168206.0	236462.0	251801.0	1223494.0
8304	285079.0	320059.0	172670.0	225287.0	240902.0	1243997.0
8334	420956.0	344699.0	228285.0	225286.0	222561.0	1441787.0
8365	482209.0	387167.0	285083.0	250098.0	313289.0	1717846.0
9031	513683.0	518704.0	257345.0	339625.0	367899.0	1997256.0
9059	456585.0	469187.0	257105.0	275997.0	329807.0	1788681.0
9090	420114.0	390094.0	205323.0	242742.0	231629.0	1489902.0
9120	340443.0	327233.0	170219.0	213845.0	193756.0	1245496.0
9151	242876.0	271886.0	155963.0	225478.0	200167.0	1096370.0
9181	187262.0	305160.0	169929.0	231891.0	227457.0	1121699.0
9212	204144.0	366937.0	168173.0	252106.0	249660.0	1241020.0
9243	209958.0	354127.0	165796.0	262108.0	273416.0	1265405.0
9273	191800.0	312246.0	178868.0	214191.0	247113.0	1144218.0

AFLC Energy Consumption

OO-ALC	OC-ALC	SM-ALC	SA-ALC	WR-ALC	TOTAL
437.0	110.0	44.0	14.0	57.0	662.0
866.0	387.0	357.0	238.0	280.0	2128.0
1049.0	697.0	569.0	426.0	537.0	3278.0
1198.0	832.0	661.0	341.0	658.0	3690.0
987.0	402.0	435.0	310.0	290.0	2424.0
952.0	442.0	449.0	149.0	168.0	2160.0
516.0	159.0	389.0	27.0	62.0	1153.0
173.0	129.0	69.0	0.	17.0	388.0
105.0	0.	1.0	0.	0.	106.0
0.	0.	0.	0.	0.	0.
6.0	0.	0.	0.	0.	6.0
47.0	29.0	0.	0.	0.	76.0
396.0	296.0	44.0	129.0	163.0	1028.0
626.0	537.0	252.0	351.0	456.0	2222.0
1052.0	658.0	567.0	536.0	593.0	3406.0
1189.0	849.0	650.0	680.0	867.0	4235.0
898.0	480.0	294.0	281.0	506.0	2459.0
955.0	362.0	424.0	134.0	1902.0	3777.0
397.0	92.0	92.0	28.0	52.0	661.0
420.0	1.0	187.0	0.	0.	608.0
0.	0.	9.0	0.	0.	9.0
0.	0.	0.	0.	0.	0.
21.0	0.	0.	0.	0.	21.0
98.0	1.0	17.0	0.	0.	116.0
362.0	73.0	68.0	18.0	121.0	642.0
728.0	400.0	309.0	144.0	202.0	1783.0
917.0	725.0	472.0	358.0	554.0	3026.0
1011.0	1163.0	451.0	628.0	754.0	4007.0
823.0	1002.0	362.0	492.0	617.0	3296.0
642.0	566.0	235.0	181.0	321.0	1945.0
526.0	93.0	269.0	18.0	62.0	968.0
297.0	62.0	46.0	0.	12.0	417.0
70.0	0.	0.	0.	0.	70.0
2.0	0.	0.	0.	0.	2.0
26.0	0.	0.	0.	0.	26.0
184.0	2.0	11.0	0.	0.	197.0
298.0	89.0	51.0	4.0	70.0	512.0
865.0	396.0	449.0	138.0	130.0	1978.0
1188.0	748.0	715.0	375.0	467.0	3493.0
1318.0	1158.0	624.0	628.0	675.0	4403.0
936.0	865.0	444.0	365.0	541.0	3151.0
806.0	379.0	313.0	109.0	226.0	1833.0
550.0	175.0	236.0	24.0	62.0	1047.0
297.0	60.0	57.0	3.0	7.0	424.0
105.0	0.	2.0	0.	0.	107.0
0.	0.	0.	0.	0.	0.
1.0	0.	0.	0.	0.	1.0
42.0	2.0	0.	0.	3.0	47.0

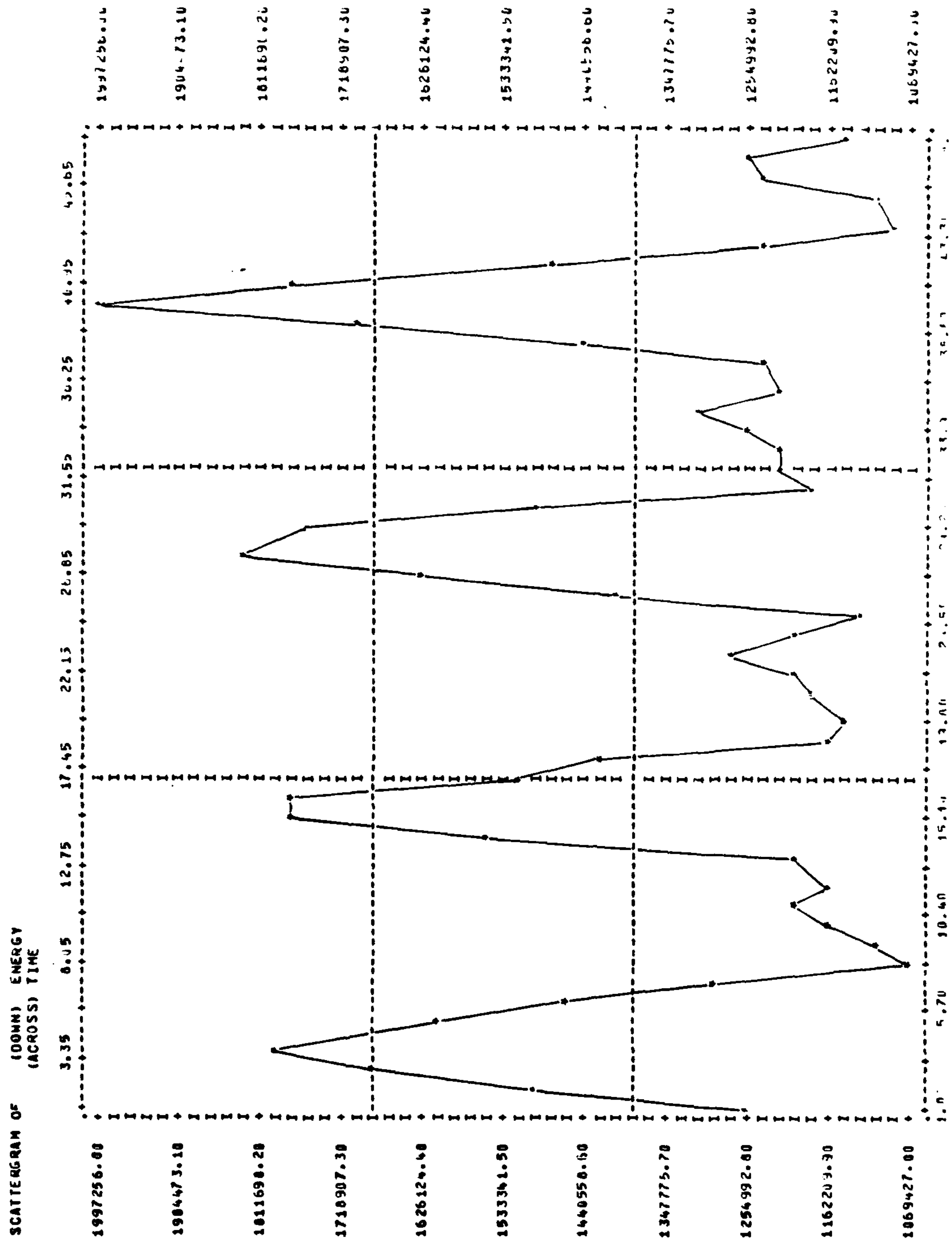
Heating Degree Days

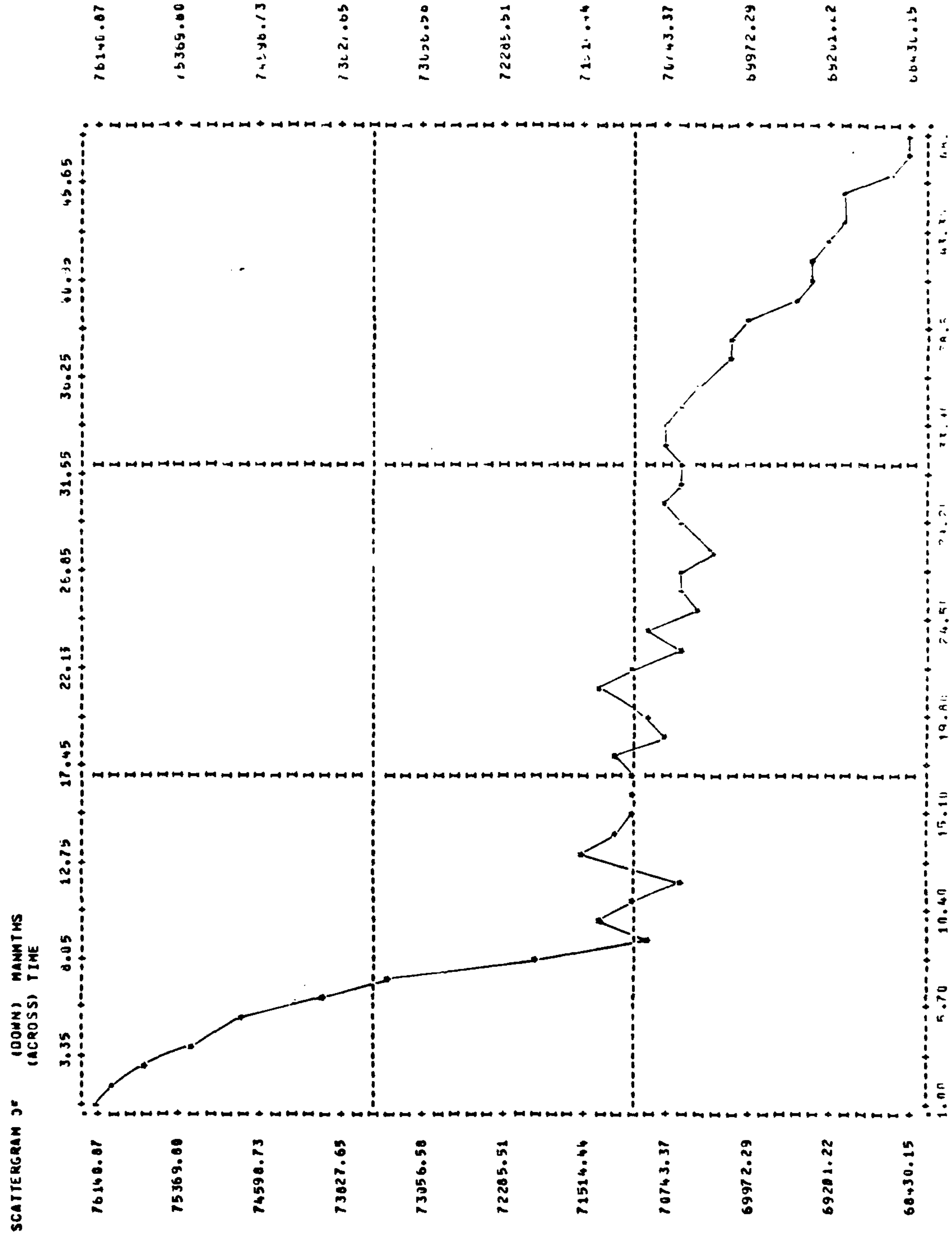
OO-ALC	OC-ALC	SM-ALC	SA-ALC	WR-ALC	TOTAL
4.0	89.0	89.0	171.0	113.0	466.0
0.	8.0	0.	31.0	40.0	79.0
0.	0.	0.	5.0	0.	5.0
0.	0.	0.	26.0	0.	26.0
0.	0.	0.	0.	4.0	4.0
0.	15.0	0.	50.0	28.0	93.0
0.	20.0	0.	151.0	70.0	241.0
18.0	35.0	171.0	285.0	148.0	657.0
112.0	250.0	258.0	433.0	347.0	1400.0
379.0	379.0	388.0	506.0	514.0	2166.0
237.0	437.0	375.0	499.0	457.0	2005.0
81.0	172.0	375.0	311.0	297.0	1236.0
0.	21.0	83.0	58.0	63.0	225.0
0.	0.	8.0	2.0	0.	10.0
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	4.0	0.	4.0
0.	8.0	0.	37.0	34.0	79.0
0.	56.0	12.0	78.0	127.0	273.0
2.0	231.0	19.0	292.0	296.0	840.0
237.0	471.0	233.0	455.0	520.0	1916.0
354.0	577.0	290.0	576.0	574.0	2371.0
245.0	505.0	284.0	617.0	512.0	2163.0
101.0	408.0	139.0	518.0	397.0	1563.0
0.	61.0	40.0	192.0	40.0	333.0
0.	1.0	0.	29.0	18.0	48.0
0.	0.	0.	0.	4.0	4.0
0.	0.	0.	2.0	0.	2.0
0.	0.	0.	6.0	0.	6.0
0.	2.0	0.	30.0	9.0	41.0
0.	60.0	0.	180.0	87.0	327.0
17.0	168.0	98.0	444.0	244.0	971.0
102.0	376.0	156.0	558.0	481.0	1673.0
322.0	600.0	321.0	434.0	546.0	2223.0
253.0	464.0	315.0	551.0	504.0	2087.0
85.0	378.0	156.0	390.0	405.0	1414.0
0.	73.0	87.0	157.0	76.0	393.0
0.	12.0	0.	82.0	25.0	119.0
0.	3.0	0.	10.0	8.0	21.0
0.	0.	0.	1.0	0.	1.0
0.	0.	0.	9.0	1.0	10.0
0.	17.0	0.	49.0	18.0	84.0
0.	30.0	0.	150.0	57.0	237.0
0.	149.0	117.0	294.0	210.0	770.0
122.0	327.0	220.0	400.0	375.0	1444.0
312.0	503.0	0.	510.0	505.0	1830.0
265.0	495.0	260.0	520.0	514.0	2054.0
107.0	266.0	296.0	336.0	312.0	1317.0

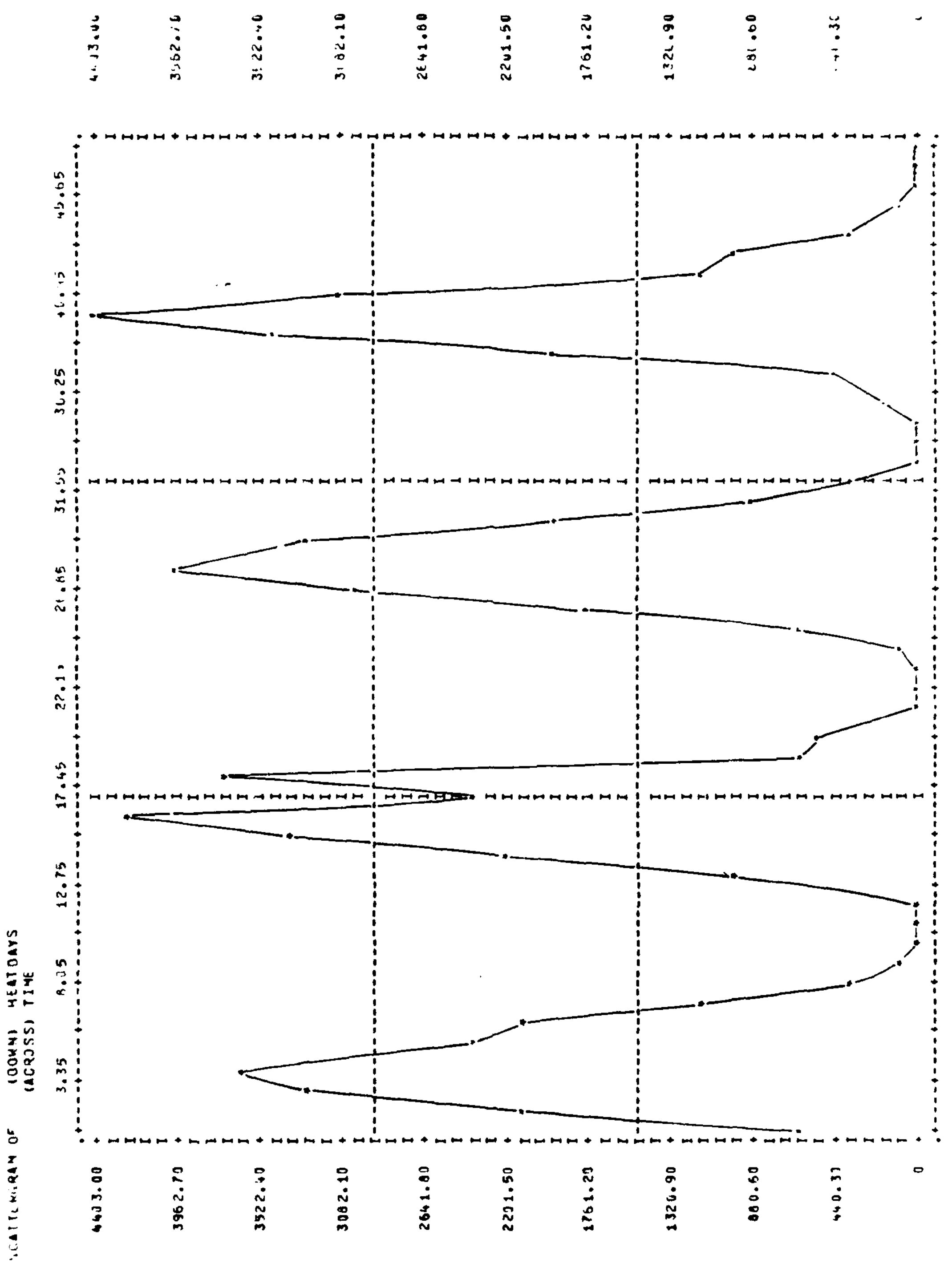
Cooling Degree Days

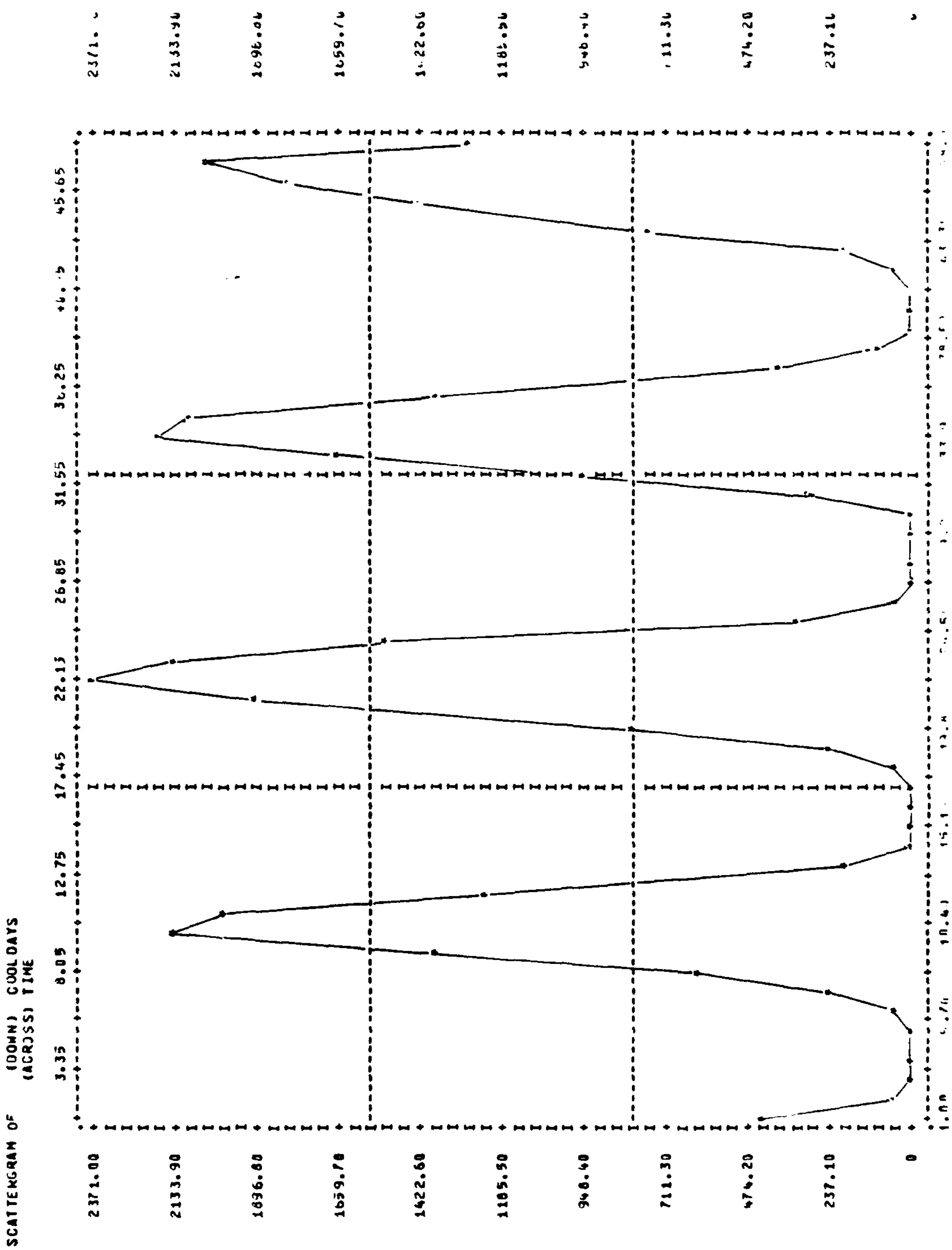
APPENDIX F

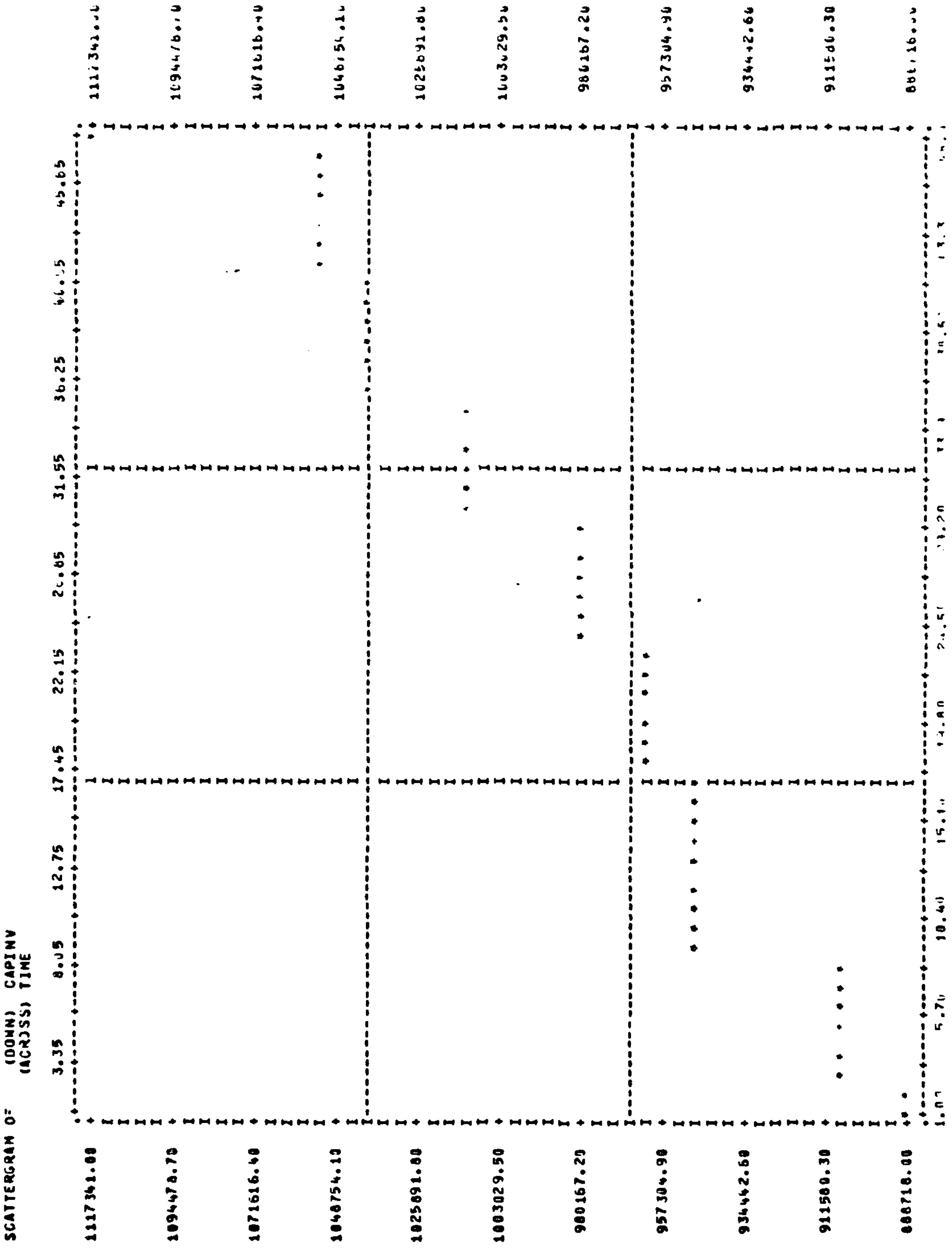
SCATTER PLOTS OF VARIABLES

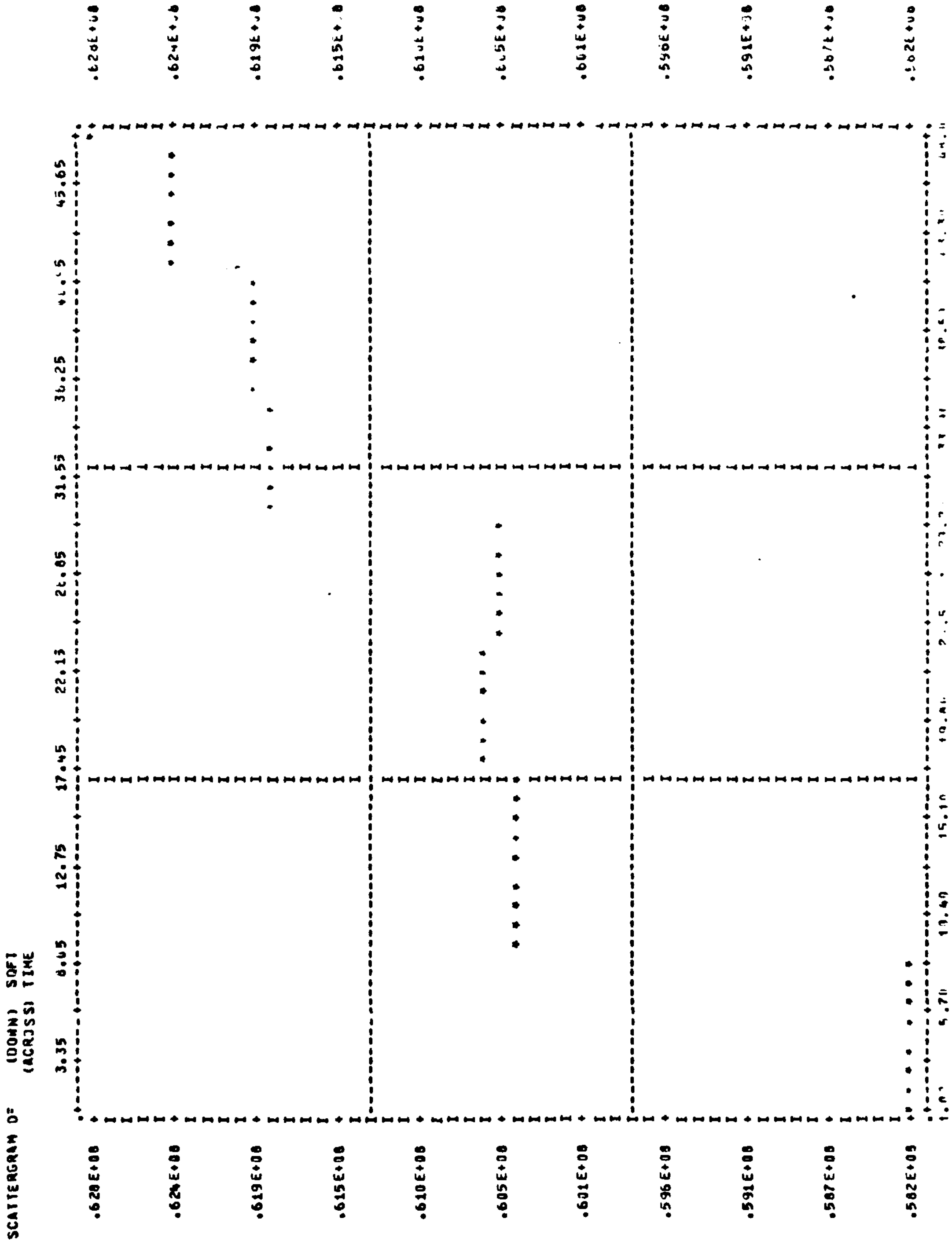

SCATTERGRAM OF (DOWN) ENERGY (ACROSS) TIME
1997256.00
1904473.10
1811690.20
1718907.30
1626124.40
1533341.50
1440558.60
1347775.70
1254992.80
1162209.90
1069427.00
3.35
12.75
17.45
22.15
26.85
31.55
36.25
5.70
10.40


SCATTERGRAM OF (DOWN) MANMTHS
(ACROSS) TIME
76140.87
75369.80
74598.73
73827.65
73056.58
72285.51
71514.44
70743.37
69972.29
69201.22
68430.15
1.00
3.35
5.70
8.05
10.40
12.75
15.10
17.45
19.80
22.15
24.50
26.85
31.55
36.25
45.65
69972.29

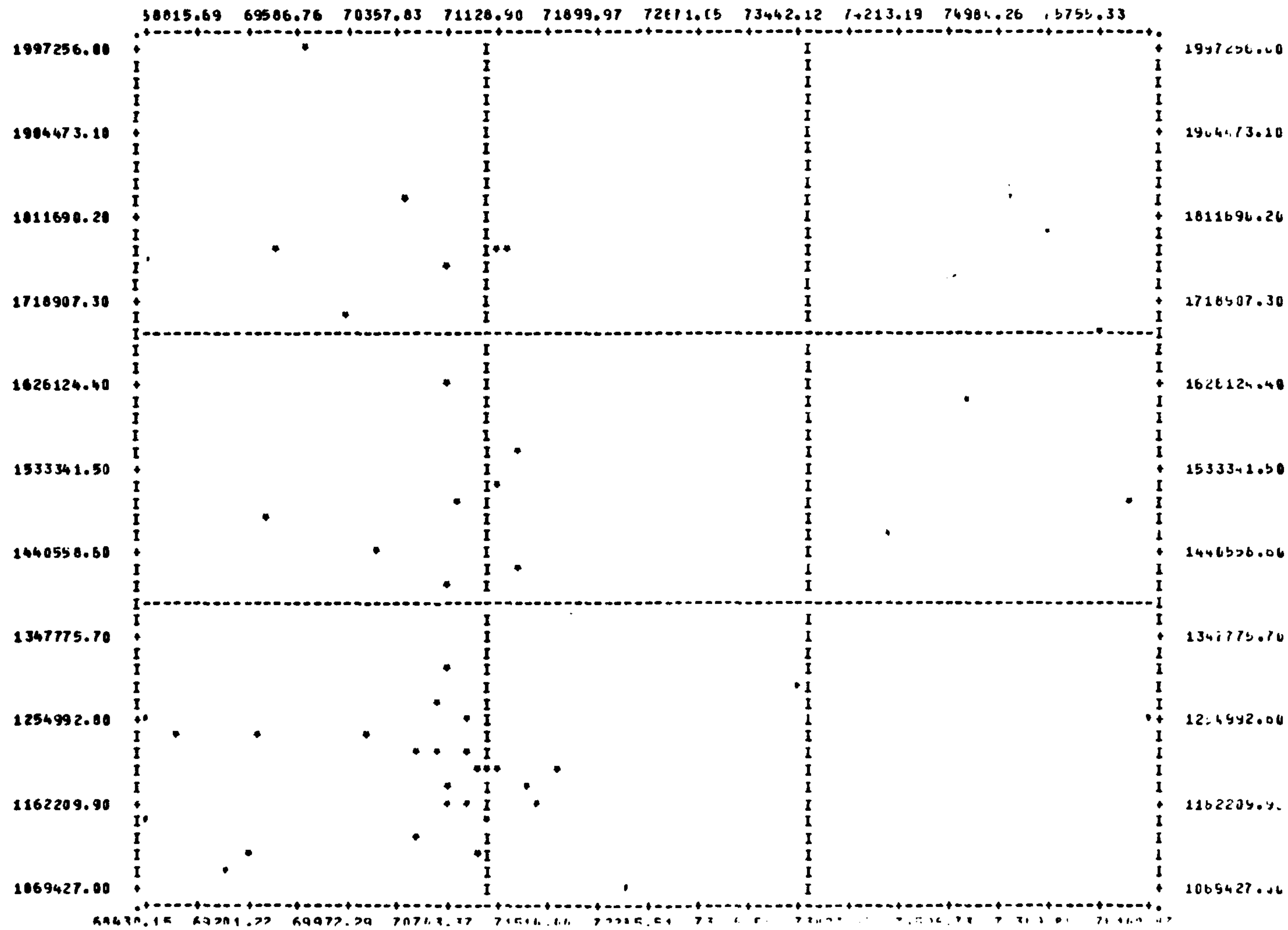

SCATTERGRAM OF (DOWN) HEATDAYS
(ACROSS) TIME
4403.00
3962.70
3082.10
2641.80
2201.50
1761.20
1320.90
880.60
440.31
0
3.35
12.75
17.45
45.65


SCATTERGRAM OF (DOWN) COOLDAYS
(ACROSS) TIME
3.35
8.05
12.75
17.45
22.15
26.85
31.55
36.25
45.65
2371.00
2133.90
1896.80
1659.70
1422.60
1185.50
948.40
711.30
474.20
237.10
0
1.00

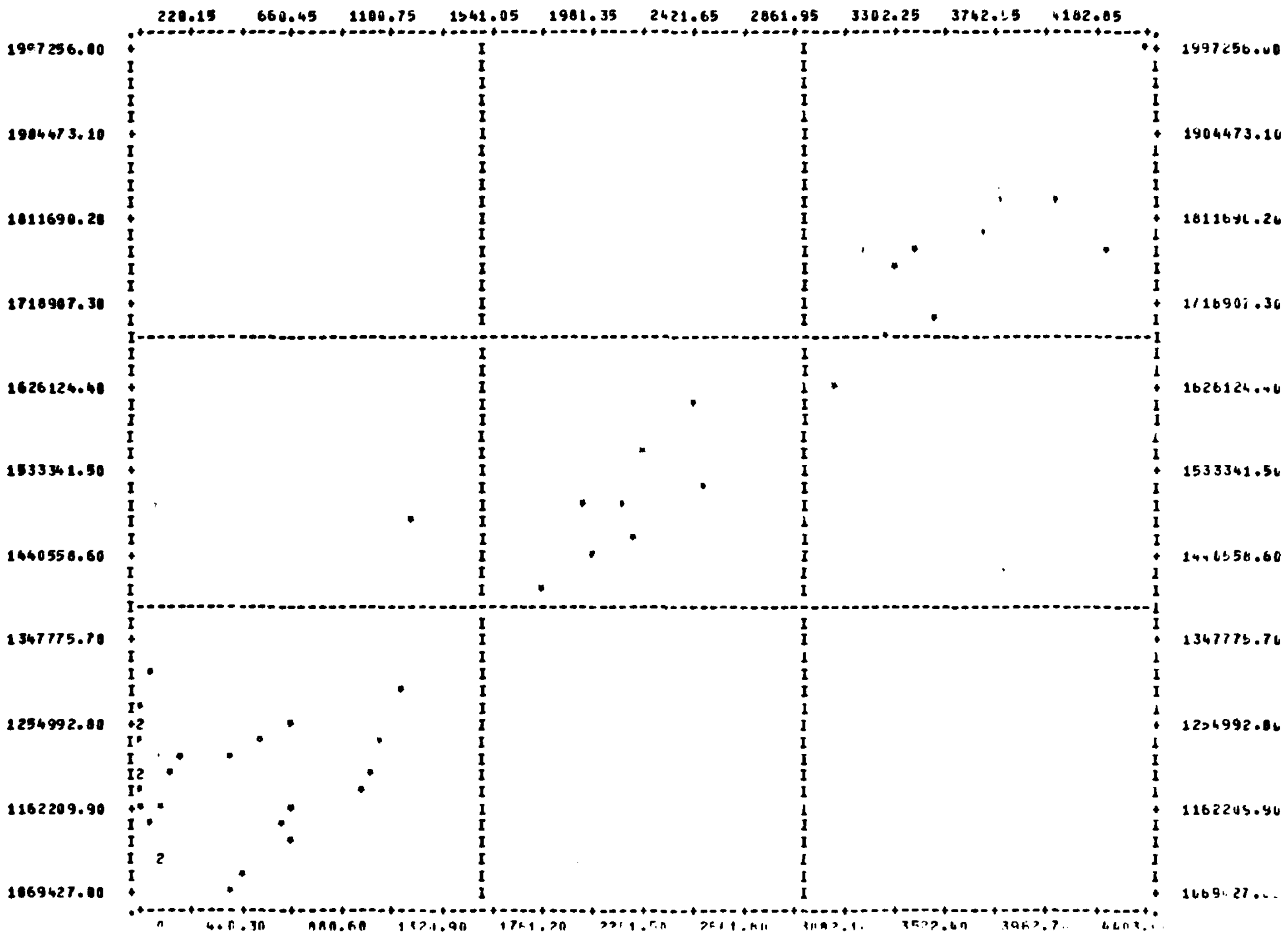

SCATTERGRAM OF (DOWN) CAPINV
(ACROSS) TIME
1117341.00
1094478.70
1071616.40
1048754.10
1025891.80
1003029.50
980167.20
957304.90
934442.60
911580.30
888718.00
3.35
12.75
17.45
22.15
31.55
36.25
45.65

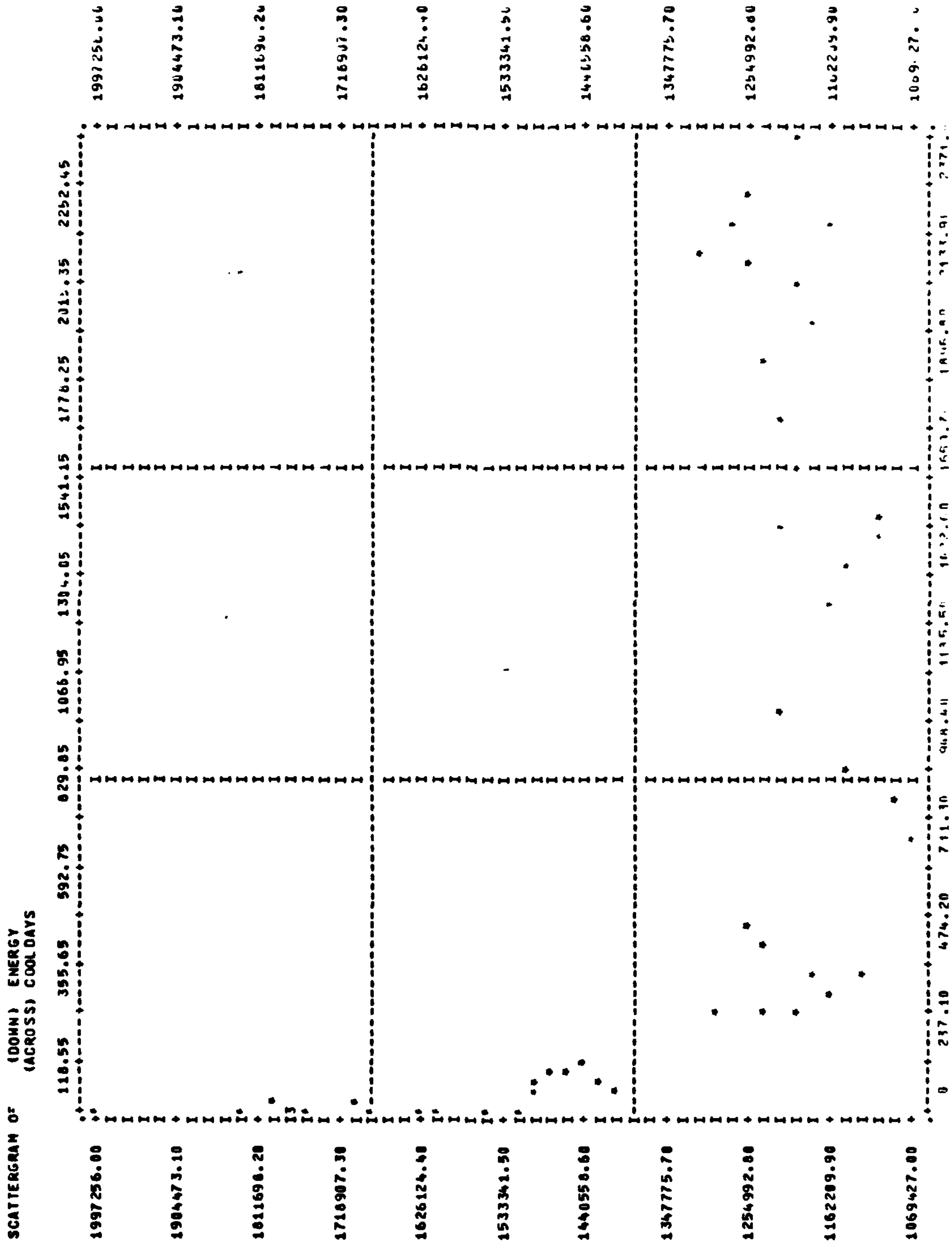

SCATTERGRAM OF (DOWN) SOFI
(ACROSS) TIME
3.35
12.75
17.45
26.85
31.55
36.25
45.65
.628E+08
.624E+08
.619E+08
.615E+08
.610E+08
.605E+08
.601E+08
.596E+08
.591E+08
.587E+08
.582E+08

SCATTERGRAM OF (DOWN) ENERGY
(ACROSS) MANMTHS

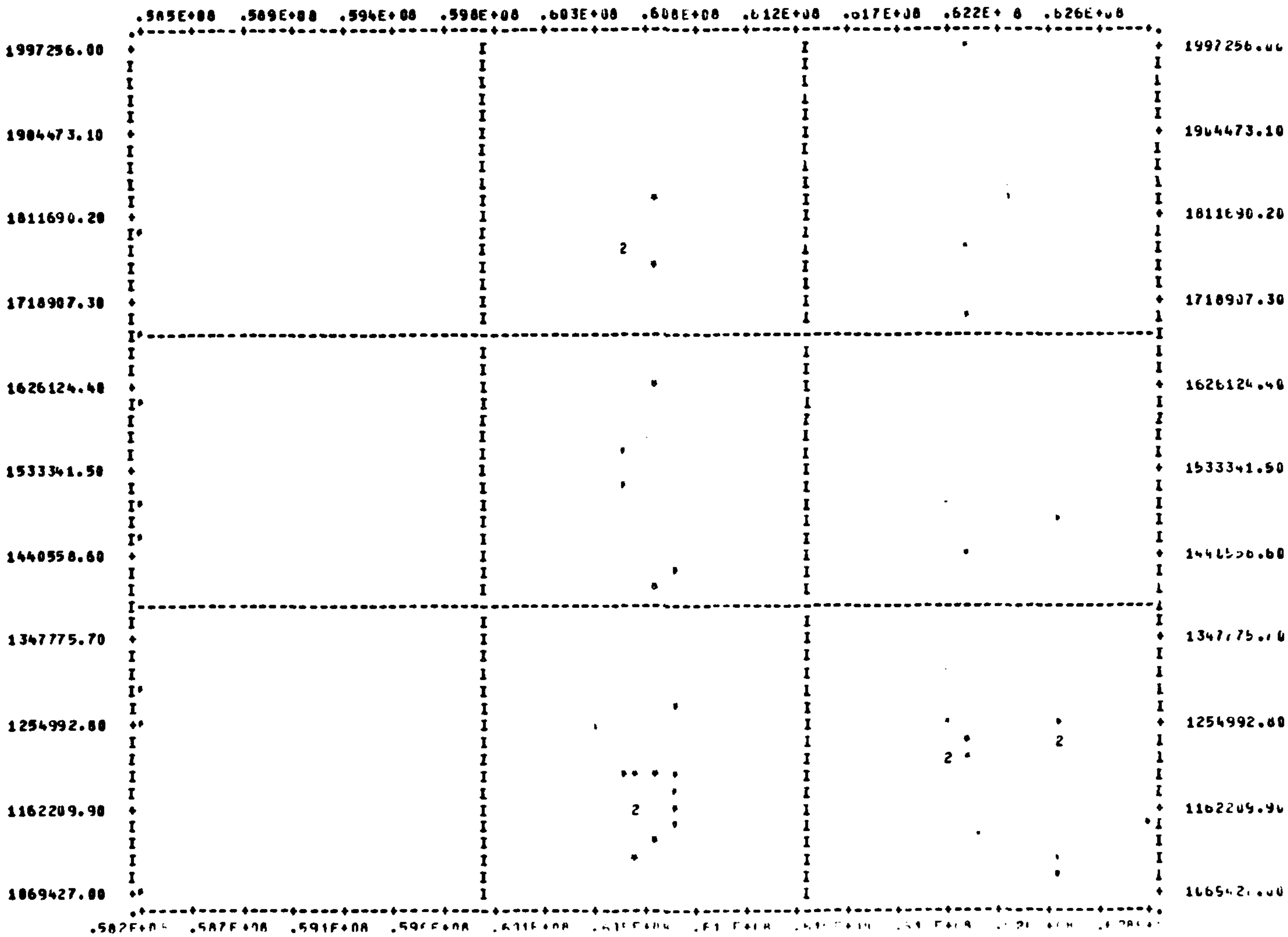


SCATTERGRAM OF (DOWN) ENERGY
(ACROSS) HEATDAYS

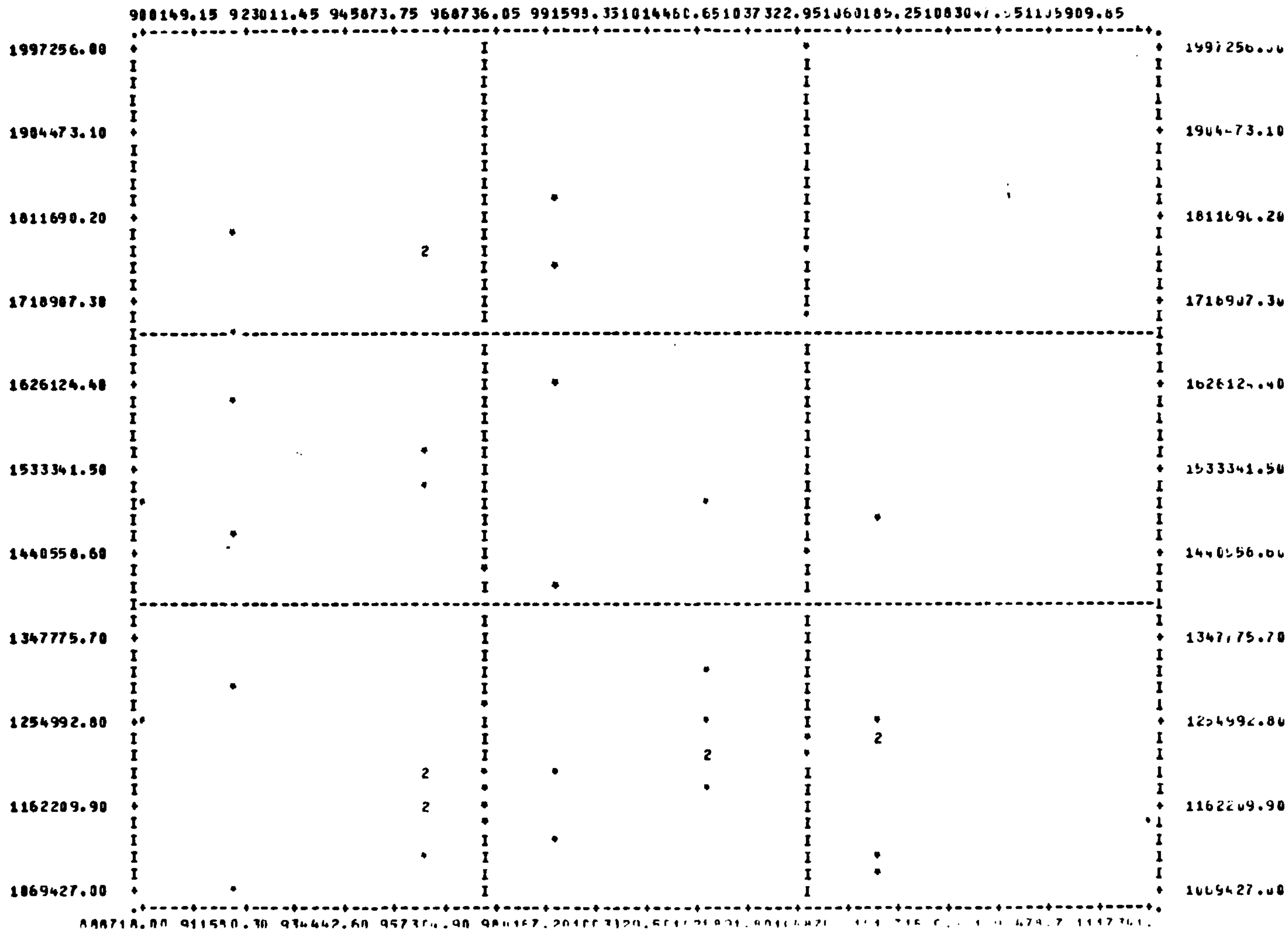



SCATTERGRAM OF (DOWN) ENERGY
(ACROSS) COOL DAYS
118.55
355.65
592.75
829.85
1066.95
1304.05
1541.15
1778.25
2015.35
2252.45
1997256.00
1904473.10
1811690.20
1718907.30
1626124.40
1533341.50
1440558.60
1347775.70
1254992.80
1162209.90
1069427.00
0
237.10
474.20
711.30

SCATTERGRAM OF (DOWN) ENERGY
(ACROSS) SOFT



SCATTERGRAM OF (DOWN) ENERGY
(ACROSS) CAPINV



APPENDIX G

SPSS REGRESSION--ENERGY WITH HEAT DAYS AND COOL DAYS EER

VARIABLE	MEAN	STANDARD DEV	CASES
ENERGY	1393[illegible]78.4732	246553.6[illegible]17	48
MANMTHS	71158.336[illegible]	1664.6539	48
HEATDAYS	1[illegible]92.875[illegible]	1433.2572	48
COOLDAYS	733.625[illegible]	822.495[illegible]	48
SQFT	6[illegible]846[illegible]16.5417	1335190.9652	48
CAPINV	93[illegible]61.2917	539[illegible]8.9342	48

CORRELATION COEFFICIENTS.

A VALUE OF 99.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.

MANMTHS	.20330				
HEATDAYS	.[illegible]2681	.24389			
COOLDAYS	-.[illegible]2112	-.2851[illegible]	-.761[illegible]0		
SQFT	-.18054	-.9[illegible]517	-.256[illegible]1	.29864	
CAPINV	-.13387	-.86186	-.21231	.21721	.9[illegible]2[illegible]5
	ENERGY	MANMTHS	HEATDAYS	COOLDAYS	SQFT

```
ALC ENERGY REGRESSION RESEARCH QUESTION TWO.                                  05/07/81      23.26.5 .      PAGE     4
UNMANIPULATED REGRESSION
FILE    NONAME    (CREATION DATE =  05/07/81 )

* * * * * * * * * * * * * * * * * * * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * * * * * * * * * * * * * * *

DEPENDENT VARIABLE..     ENERGY

PARAMETERS..  MAXIMUM STEP   10     F TO ENTER       7.310
              TOLERANCE    .0010    F TO REMOVE      4.080

MEAN RESPONSE  1323478.47917       STD. DEV.  246550.66174

VARIABLE(S) ENTERED ON STEP NUMBER   1..    HEATDAYS

MULTIPLE R              .92681         ANALYSIS OF VARIANCE    DF      SUM OF SQUARES          MEAN SQUARE             F      SIGNIFICANCE
R SQUARE                .85899         REGRESSION               1.2454120.1 0610.1502524.4120174616.15625            280.20662         .030
ADJUSTED R SQUARE       .85592         RESIDUAL                46. 41207955314.31836  8758251837.39819
STD DEVIATION     93585.53204          COEFF OF VARIABILITY     5.8 PCT

-------------------- VARIABLES IN THE EQUATION ---------------------        ---------- VARIABLES NOT IN THE EQUATION -----------

VARIABLE           B           STD ERROR B          F             BETA         VARIABLE       PARTIAL    TOLERANCE        F
                                               ------------   ----------                                              ------------
                                               SIGNIFICANCE   ELASTICITY                                              SIGNIFICANCE

HEATDAYS      159.43176        9.5243565       280.20662       .9265145        MANMTHS       -.06241       .94052       .17594974
                                                       0       .11167                                                      .677
(CONSTANT)   1159815.6         18999.816       3726.3138                       COOLDAYS       .43994       .38941      11.860080
                                                    .030                                                                   .002
                                                                               SOFT           .16243       .93322      1.2209569
                                                                                                                           .275
                                                                               CAPINV         .17162       .95493      1.3623326
                                                                                                                           .249
```

ALC ENERGY REGRESSION RESEARCH QUESTION TWO. 05/07/83 23.26.51 PAGE 5
UNMANIPULATED REGRESSION
FILE NONAME (CREATION DATE = 05/07/83)

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. ENERGY

VARIABLE(S) ENTERED ON STEP NUMBER 2.. COOLDAYS

MULTIPLE R	.94142	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.88628	REGRESSION	2.	2632[illegible]97330[illegible]87.[illegible]	625012[illegible]243.53125	175.35169	.000
ADJUSTED R SQUARE	.88122	RESIDUAL	45.	324[illegible]2423269.40430	7220153650.43118		
STD DEVIATION	84973.91082	COEFF OF VARIABILITY	5.1 PCT				

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
HEATDAYS	19[illegible].61812	13.8[illegible]7863	196.04357 / 0	1.1335[illegible] / .19775
COOLDAYS	79.359537	24.148239	10.600686 / .002	.2647[illegible]39 / .04208
(CONSTANT)	1031672.3	37154.443	861.19769 / 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
MANMTHS	.00712	.91758	.22287604E-02 / .963
SOFT	.10373	.96926	.47861224 / .493
CAPINV	.15020	.94816	1.0154903 / .319

F-LEVEL OR TOLERANCE-LEVEL INSUFFICIENT FOR FURTHER COMPUTATION.

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. ENERGY

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	HEATDAYS		280.20662	0	.92561	.85899	.85899	.92561	280.20662	.000
2	COOLDAYS		10.60066	.002	.94142	.88628	.02729	-.62112	175.35169	.000

* M U L T I P L E   R E G R E S S I O N *

OBSERVATION	Y VALUE	Y ESTIMATE	RESIDUAL	ERROR	-2SD … 0.0 … +2SD
1.	1269134.	1216169.	52965.35	4.17%	
2.	15[illegible]317.	14729[illegible].	31370.72	2.09%	
3.	16911[illegible].	1691339.	-190.5331	0.01%	
4.	1810[illegible]3.	1773353.	37310.48	2.06%	
5.	1608809.	1524714.	84095.32	5.23%	
6.	1461637.	143[illegible]212.	-18594.59	1.27%	
7.	1294037.	1295654.	-1616.450	0.12%	
8.	1069427.	1179479.	-110[illegible]1.[illegible]	1.03%	
9.	1116399.	1163448.	-57050.55	6.01%	
10.	1164734.	12235[illegible].	-56831.61	5.05%	
11.	1205211.	1211958.	-6747.237	0.56%	
12.	1106868.	1104582.	2285.955	0.20%	
13.	1205176.	1270245.	-65069.31	5.39%	
14.	1568016.	1485736.	62213.93	5.24%	
15.	1776677.	1715934.	60972.37	3.43%	
16.	1782676.	1877574.	-94898.65	5.32%	
17.	1531889.	1531539.	348.0950	0.02%	
18.	1427151.	1794525.	-367374.2	25.7%	R
19.	1169989.	1202244.	-32255.44	2.76%	
20.	1161711.	1236915.	-75194.32	6.47%	
21.	1186039.	1205486.	-19471.30	1.64%	
22.	1207436.	1239834.	-32397.71	2.68%	
23.	1283786.	1227422.	56363.69	4.54%	
24.	1210281.	1198333.	11947.57	0.99%	
25.	1126707.	1203311.	-76593.57	6.80%	
26.	1409935.	1403139.	6796.120	0.48%	
27.	164290[illegible].	1642115.	789.4165	0.05%	
28.	1841439.	18332[illegible]9.	8220.361	0.45%	
29.	1766237.	1694926.	71306.31	4.04%	
30.	1496745.	1434236.	62509.70	4.18%	
31.	1186527.	1264400.	-77873.42	6.55%	
32.	12165[illegible].	1210[illegible]53.	6497.146	0.70%	
33.	1235513.	1198012.	37420.35	3.03%	
34.	1259131.	1228479.	30702.46	2.44%	
35.	1328490.	1222356.	106131.9	7.99%	
36.	1223494.	1202315.	21188.77	1.73%	
37.	1243937.	1182710.	61287.12	4.93%	
38.	1441787.	1446[illegible]2.	-5074.976	0.35%	
39.	1717846.	1734537.	-16691.16	0.97%	
40.	1997236.	1910410.	86039.56	4.35%	
41.	1788081.	1666[illegible].	121713.6	6.80%	
42.	1489912.	1269[illegible]5.	220857.6	13.5%	R
43.	1245[illegible].	1274[illegible].	-29160.45	2.34%	
44.	1096371.	1195437.	-99090.52	9.04%	
45.	1121[illegible].	1187134.	-65435.36	5.83%	
46.	1241020.	1196930.	44119.79	3.56%	
47.	121[illegible].	1214672.	50533.20	3.99%	
48.	1144216.	1165335.	-21130.64	1.83%	

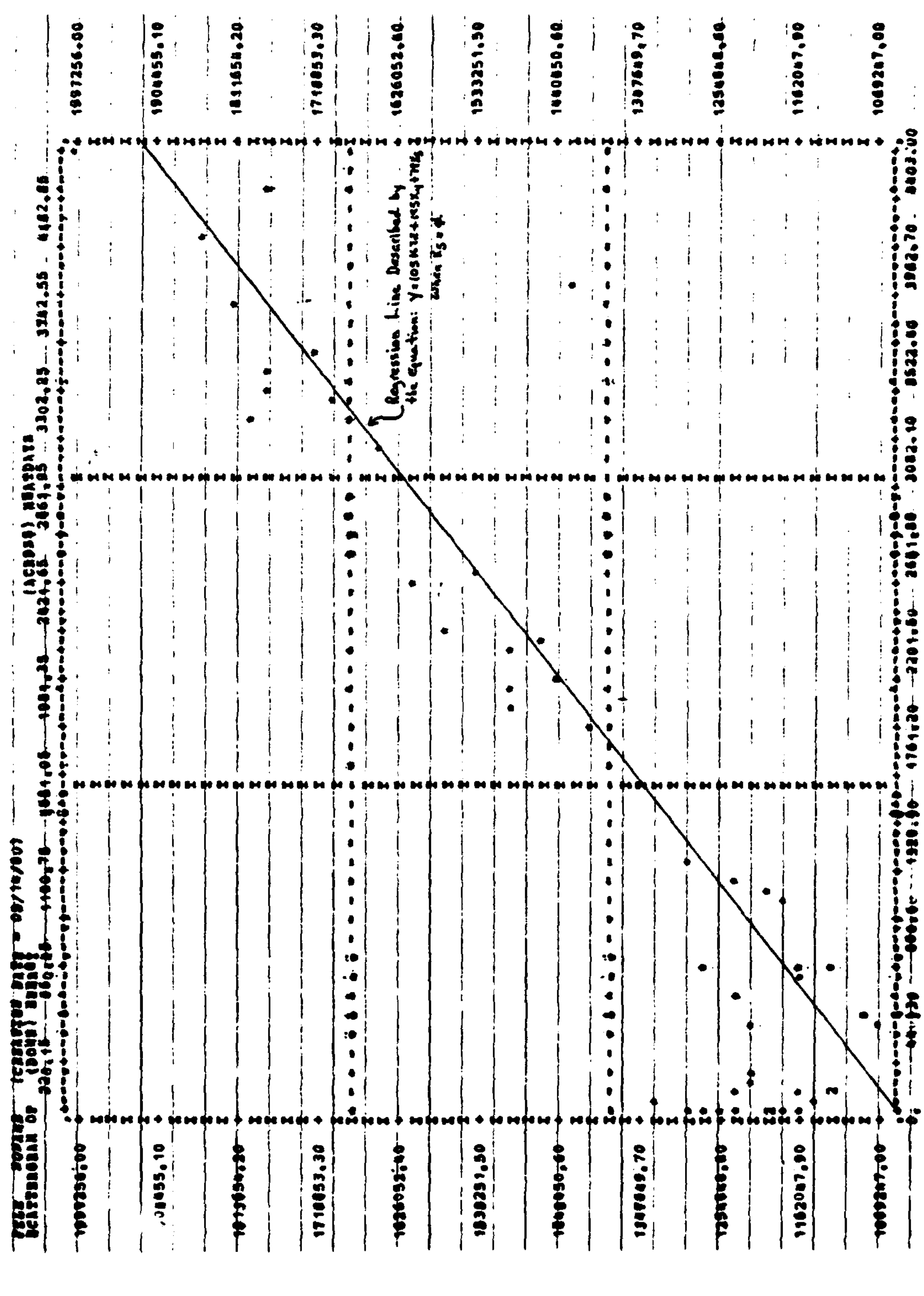
NOTE - (*) INDICATES ESTIMATE CALCULATED WITH MEANS SUBSTITUTED
R INDICATES POINT OUT OF RANGE OF PLOT

AD-A087 083 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL--ETC F/G 13/1
ENERGY SELF-SUFFICIENCY FOR AIR FORCE LOGISTICS COMMAND (AFLC) --ETC(U)
JUN 80 C R HATCH, R E MANSFIELD
UNCLASSIFIED AFIT-LSSR-01-80 NL

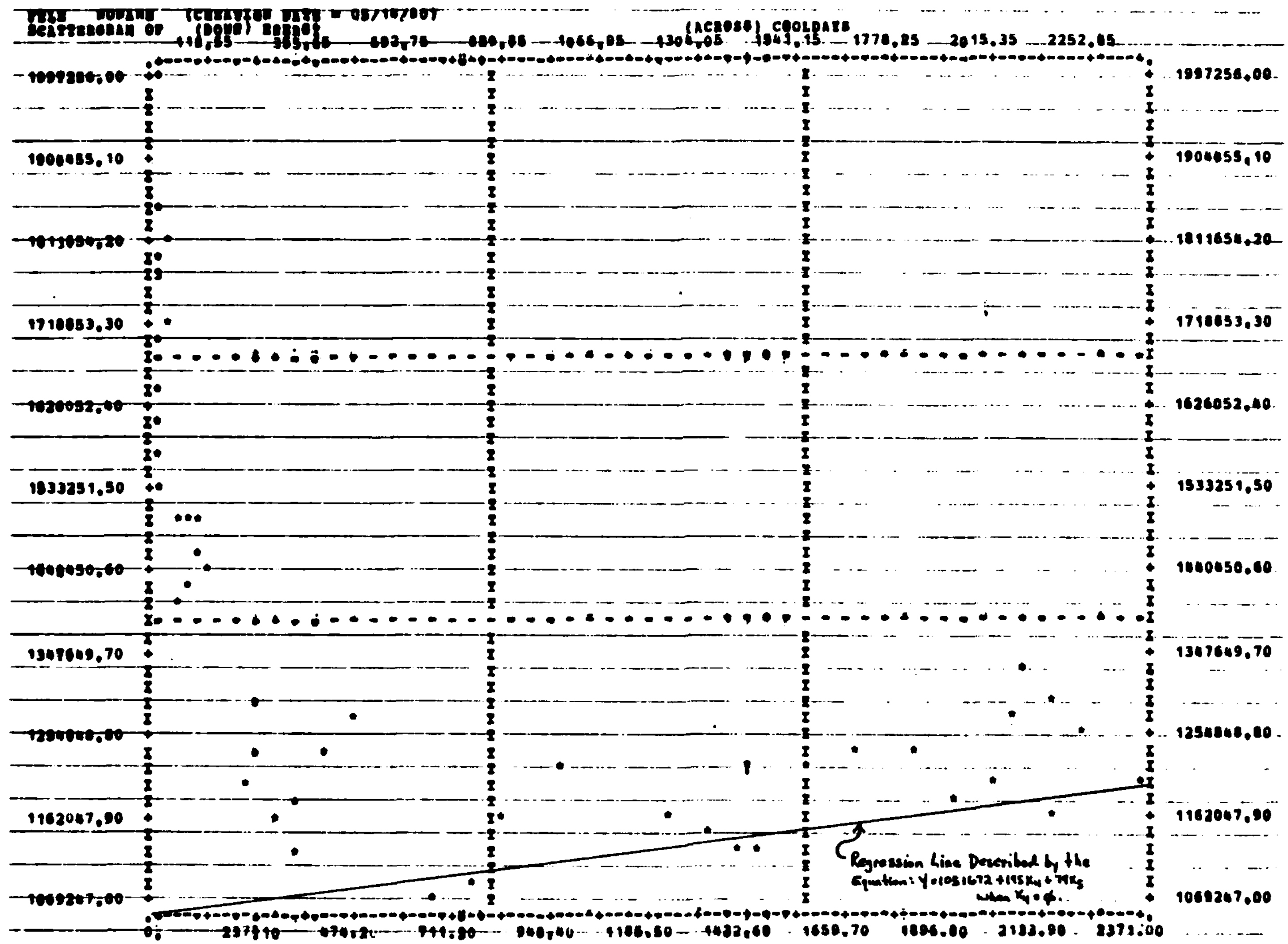
4 OF 4
ADA
087083

END
DATE
FILMED
9-80
DTIC

```
NUMBER OF CASES PLOTTED          48.
NUMBER OF 2 S.D. OUTLIERS         2. OR   4.17 PERCENT OF THE TOTAL


ALC ENERGY REGRESSION RESEARCH QUESTION TWO.                                    05/17/80
UNMANIPULATED REGRESSION,FIN-FOUT
FILE    NONAME    (CREATION DATE =  05/17/80 )

* * * * * * * * * * * * * * * * * * * * * * M U L T I P L E   R E G R E S S I O N *

VON NEUMANN RATIO     1.62132          DURBIN-WATSON TEST     1.58755

NUMBER OF POSITIVE RESIDUALS      26.
NUMBER OF NEGATIVE RESIDUALS      22.
NUMBER OF RUNS OF SIGNS           20.

EXPECTED NUMBER OF RUNS OF SIGNS             25.
EXPECTED S.D. OF RUN DISTRIBUTION       3.40273
UNIT NORMAL DEVIATE-
  Z=(EXPECTED-OBSERVED)/S.D.           -1.27349
PROBABILITY OF OBTAINING .GE. ABS(Z)     .10142


RESIDUALS -         48 CASES WRITTEN ON FILE RCDOUT
```



Regression Line Described by

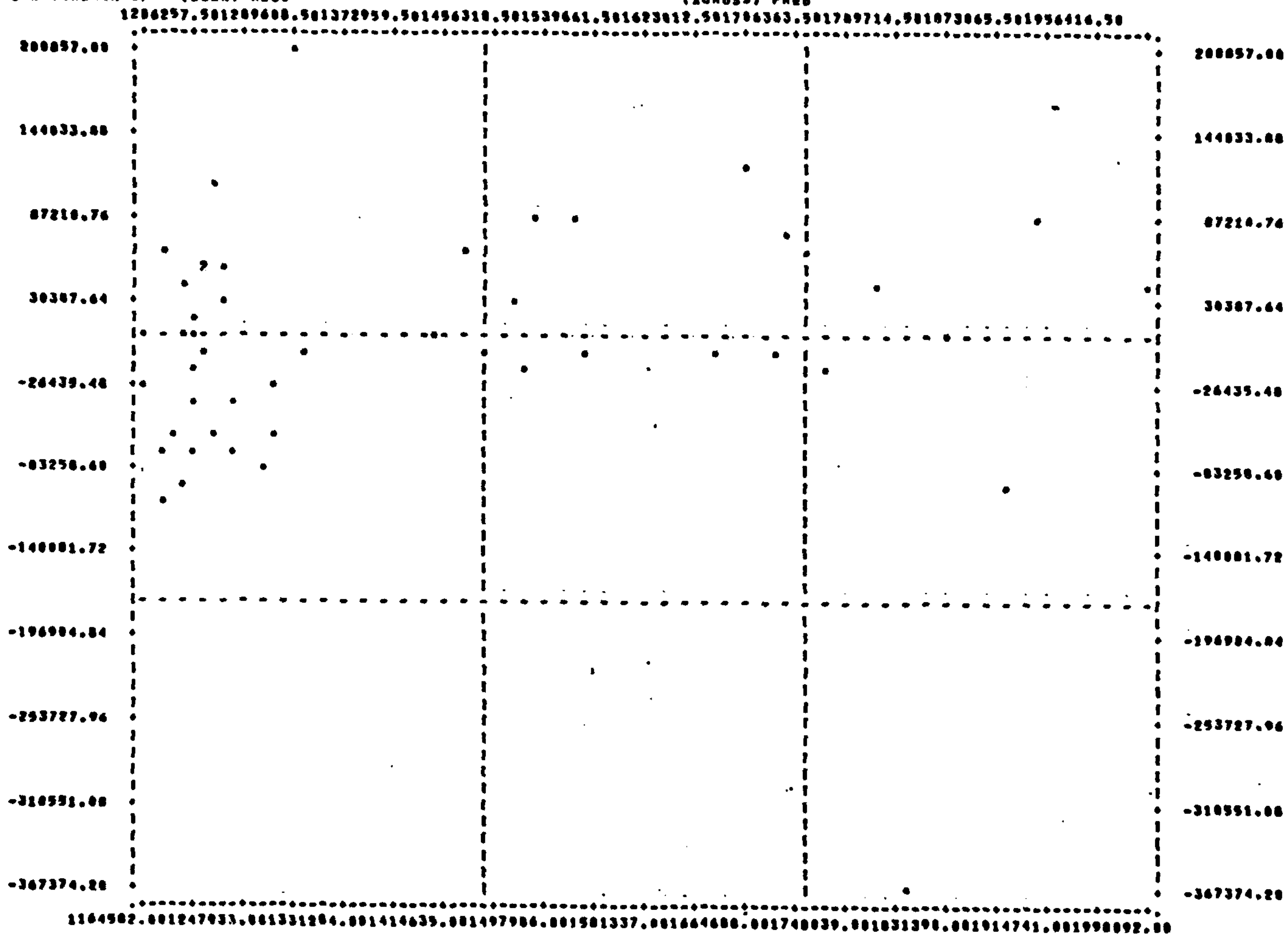

(ACROSS) COOLDAYS
2015.35
2252.85
1997256.00
1904455.10
1811654.20
1718853.30
1626052.40
1533251.50
1440450.60
1347649.70
1254848.80
1162047.90
1069247.00
1659.70
1896.80
2133.90
2371.00
Regression Line Described by the
Equation: Y = 1051672 + 195X4 + 79X5
when X4 = 0.

APPENDIX H

TESTS FOR APTNESS OF MODEL

RESIDUALS OF ENERGY REGRESSED WITH HEATDAYS AND COOLDAYS 05/19/88 PAGE 2

FILE NONAME (CREATION DATE = 05/19/88)
SCATTERGRAM OF (DOWN) RESD (ACROSS) PRED



RESIDUALS OF ENERGY REGRESSED WITH HEATDAYS AND COOLDAYS

- - - - - KOLMOGOROV - SMIRNOV GOODNESS OF FIT TEST

RESD
TEST DIST. - NORMAL (MEAN = -0.0017 STD. DEV. = 83143.3555)

CASES	MAX(ABS DIFF)	MAX(+ DIFF)	MAX(- DIFF)
48	0.1192	0.0856	-0.1192

K-S Z	2-TAILED P
0.826	0.502

- - - - - RUNS TEST

RESD

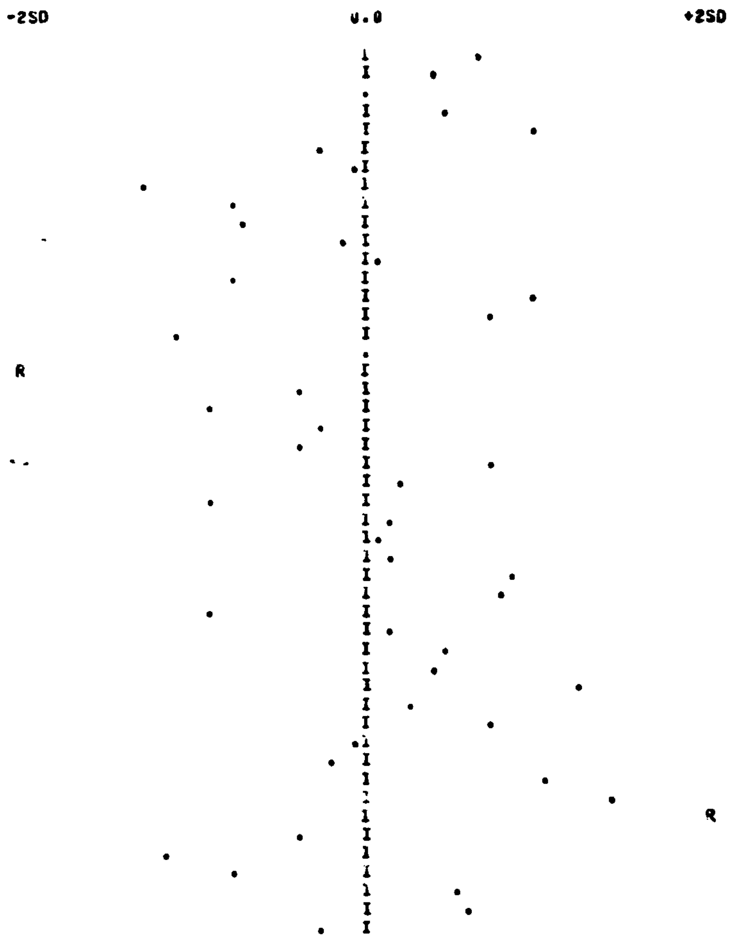
CASES	TEST VALUE	RUNS	Z	2-TAILED P
48	0.	20.	-1.420	0.155

APPENDIX I

ERROR BETWEEN FORECASTED AND ACTUAL ENERGY CONSUMPTION USING MODEL DATA BASE

MULTIPLE REGRESSION

OBSERVATION	Y VALUE	Y ESTIMATE	RESIDUAL	ERROR
1.	1269154.	1216169.	52965.35	4.17%
2.	1504317.	1472940.	31376.72	2.09%
3.	1691148.	1691339.	-190.5031	0.01%
4.	1810669.	1773353.	37316.48	2.06%
5.	1608809.	1524714.	84095.32	5.23%
6.	1461697.	1480292.	-18594.59	1.27%
7.	1294037.	1295654.	-1616.850	0.12%
8.	1069427.	1179479.	-110051.5	1.03%
9.	1116389.	1183448.	-67058.55	6.01%
10.	1164734.	1223565.	-58831.01	5.05%
11.	1205211.	1211958.	-6747.237	0.56%
12.	1166868.	1164582.	2285.955	0.20%
13.	1205175.	1270245.	-65069.31	5.39%
14.	1568010.	1485796.	82213.93	5.24%
15.	1776877.	1715904.	60972.97	3.43%
16.	1782676.	1877574.	-94898.05	5.32%
17.	1531889.	1531539.	348.0930	0.02%
18.	1427151.	1794525.	-367374.2	25.7%
19.	1169989.	1202244.	-32255.44	2.76%
20.	1161711.	1236905.	-75194.32	6.47%
21.	1186009.	1205480.	-19471.30	1.64%
22.	1207436.	1239834.	-32397.71	2.68%
23.	1265786.	1227422.	58363.69	4.54%
24.	1210281.	1198333.	11947.57	0.99%
25.	1126707.	1203301.	-76593.57	6.80%
26.	1409995.	1403199.	6796.120	0.48%
27.	1642904.	1642115.	789.4165	0.05%
28.	1841489.	1833269.	8220.361	0.45%
29.	1766237.	1694928.	71306.91	4.04%
30.	1496745.	1434236.	62509.70	4.18%
31.	1188527.	1266400.	-77873.42	6.55%
32.	1216551.	1210053.	6497.946	0.70%
33.	1235513.	1198092.	37420.95	3.03%
34.	1259181.	1228479.	30702.46	2.44%
35.	1328499.	1222356.	106131.9	7.99%
36.	1223494.	1202305.	21188.77	1.73%
37.	1243997.	1182710.	61287.12	4.93%
38.	1441787.	1446652.	-5074.938	0.35%
39.	1717846.	1734537.	-16691.16	0.97%
40.	1997256.	1910416.	86639.54	4.35%
41.	1788081.	1666958.	121713.0	6.80%
42.	1489902.	1283045.	206857.0	13.5%
43.	1245496.	1274604.	-29160.49	2.34%
44.	1096370.	1195467.	-99096.92	9.04%
45.	1121699.	1187134.	-65435.38	5.83%
46.	1241020.	1196900.	44119.79	3.56%
47.	1265405.	1214872.	50533.24	3.99%
48.	1144218.	1165355.	-21136.64	1.83%



NOTE - (*) INDICATES ESTIMATE CALCULATED WITH MEANS SUBSTITUTED
R INDICATES POINT OUT OF RANGE OF PLOT

APPENDIX J

STEPWISE REGRESSION WITH INCLUSION LEVEL UNSPECIFIED
AND SQUARE FEET, CAPITAL INVESTMENT, AND
MAN-MONTHS REGRESSED SEPARATELY

ALC ENERGY REGRESSION RESEARCH QUESTION TWO.
STEPWISE, INCLUSION LEVEL UNSPECIFIED

VARIABLE	MEAN	STANDARD DEV	CASES
ENERGY	1383476.4792	246550.6617	48
MANMTHS	71158.3350	1864.6699	48
HEATDAYS	1402.8750	1433.2572	48
COOLDAYS	733.6250	822.4950	48
SQFT	6084.6416.5417	1385190.9652	48
CAPINV	984861.2917	53988.9342	48

CORRELATION COEFFICIENTS.

A VALUE OF 99.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.

MANMTHS	.20330				
HEATDAYS	.92681	.24330			
COOLDAYS	-.52112	-.28517	-.76140		
SQFT	-.18054	-.50517	-.25041	.29864	
CAPINV	-.13387	-.66186	-.21231	.21721	.95266
	ENERGY	MANMTHS	HEATDAYS	COOLDAYS	SQFT

```
ALC ENERGY REGRESSION RESEARCH QUESTION TWO.                     05/19/80      08.43.13.      PAGE    4
STEPWISE, INCLUSION LEVEL UNSPECIFIED
FILE   NONAME    (CREATION DATE =  05/19/80 )

* * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * * * * * * * * * * * *

DEPENDENT VARIABLE..     ENERGY

MEAN RESPONSE  1383478.47917       STD. DEV.  246550.66174

VARIABLE(S) ENTERED ON STEP NUMBER   1..    HEATDAYS

MULTIPLE R             .92681        ANALYSIS OF VARIANCE     DF       SUM OF SQUARES         MEAN SQUARE             F      SIGNIFICANCE
R SQUARE               .85899        REGRESSION               1.2454128179E16.15625245412817U816.15625           280.28662          .000
ADJUSTED R SQUARE      .85592        RESIDUAL                46. 4028795533140.31936   8758251807.39819
STD DEVIATION   93585.53204          COEFF OF VARIABILITY     6.8 PCT

-------------------- VARIABLES IN THE EQUATION ---------------------        ---------- VARIABLES NOT IN THE EQUATION -----------

VARIABLE          B            STD ERROR B          F           BETA         VARIABLE       PARTIAL     TOLERANCE        F
                                               ------------  -----------                                          ------------
                                               SIGNIFICANCE  ELASTICITY                                           SIGNIFICANCE

HEATDAYS     159.43176          9.5243565      280.28662      .9268145       MANMTHS        -.08241       .94052      .17594974
                                                       0       .16167                                                    .677
(CONSTANT)   1159815.5          18999.810      3726.3138                     COOLDAYS        .43934       .38941     10.860.60
                                                    .000                                                                 .002
                                                                             SQFT            .16253       .93322     1.2209569
                                                                                                                         .275
                                                                             CAPINV          .17142       .95493     1.3623320
                                                                                                                         .249

DEPENDENT VARIABLE..     ENERGY

VARIABLE(S) ENTERED ON STEP NUMBER   2..    COOLDAYS

MULTIPLE R             .93142        ANALYSIS OF VARIANCE     DF       SUM OF SQUARES         MEAN SQUARE             F      SIGNIFICANCE
R SQUARE               .86628        REGRESSION               2.2532(07333487.062501266848665243.53125           175.35169          .000
ADJUSTED R SQUARE      .88122        RESIDUAL                45. 3245(2423269.40430   7228353851.43118
STD DEVIATION   84978.98002          COEFF OF VARIABILITY     5.1 PCT

-------------------- VARIABLES IN THE EQUATION ---------------------        ---------- VARIABLES NOT IN THE EQUATION -----------

VARIABLE          B            STD ERROR B          F           BETA         VARIABLE       PARTIAL     TOLERANCE        F
                                               ------------  -----------                                          ------------
                                               SIGNIFICANCE  ELASTICITY                                           SIGNIFICANCE

HEATDAYS     195.01812         13.857809       198.04357      1.1338864      MANMTHS         .01712       .91758     .22287604E-02
                                                       0       .15775                                                    .963
COOLDAYS     79.359507         24.148239       10.800080      .2647439       SQFT            .10373       .90924     .47861224
                                                    .002       .04208                                                    .493
(CONSTANT)   1051672.3         37154.443       801.19709                     CAPINV          .15020       .94816     1.0154903
                                                       0                                                                 .319
```

```
ALC ENERGY REGRESSION RESEARCH QUESTION TWO.                          05/19/80     08.43.33.     PAGE   6
STEPWISE, INCLUSION LEVEL UNSPECIFIED
FILE    NONAME    (CREATION DATE = 05/19/80 )

* * * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E    R E G R E S S I O N  * * * * * * * * * * * * * * * * * * * * * * * *

DEPENDENT VARIABLE..     ENERGY

VARIABLE(S) ENTERED ON STEP NUMBER   3..    CAPINV

MULTIPLE R            .94279        ANALYSIS OF VARIANCE    DF       SUM OF SQUARES          MEAN SQUARE              F      SIGNIFICANCE
R SQUARE              .88884        REGRESSION               3.2539426702209.09375 846475567403.33125          117.27987          0
ADJUSTED R SQUARE     .88127        RESIDUAL                44. 317373051547.38086   7217369353.34955
STD DEVIATION    84956.27907        COEFF OF VARIABILITY     6.1 PCT
```

VARIABLES IN THE EQUATION

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
HEATDAYS	195.59654	13.889403	199.12578	1.1393742
			0	.19674
COOLDAYS	77.305005	24.230010	10.179069	.2578911
			.003	.04599
CAPINV	.23754051	.23572192	1.0154903	.0520159
			.319	.18910
(CONSTANT)	817862.49	234974.61	12.114845	
			.001	

VARIABLES NOT IN THE EQUATION

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
MANMTHS	.26449	.24656	3.2344448
			.079
SQFT	-.13155	.08346	.75719559
			.389

ALC ENERGY REGRESSION RESEARCH QUESTION TWO. 05/19/80 09.43.33. PAGE 7
STEPWISE, INCLUSION LEVEL UNSPECIFIED
FILE NONAME (CREATION DATE = 05/19/80)

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. ENERGY

VARIABLE(S) ENTERED ON STEP NUMBER 4.. MANMTHS

MULTIPLE R	.94690	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.89662	REGRESSION	4.	25616433?9667.31250	640410827416.82812	93.23536	.000
ADJUSTED R SQUARE	.88700	RESIDUAL	43.	29535644089.16211	686875?513.76142		
STD DEVIATION	82877.54950	COEFF OF VARIABILITY	6.0 PCT				

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
HEATDAYS	197.15134	13.564825	211.23753 / 0	1.1460873 / .15952
COOLDAYS	84.327143	23.957576	12.389366 / .001	.2817160 / .14472
CAPINV	.91976484	.44359597	4.2991087 / .044	.2814874 / .65176
MANMTHS	23.480709	13.056036	3.2344448 / .079	.1775153 / 1.20772
(CONSTANT)	-1831653.7	1326365.1	1.3335664 / .255	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
SQFT	.06663	.06106	.18446395E-02 / .966

F-LEVEL OR TOLERANCE-LEVEL INSUFFICIENT FOR FURTHER COMPUTATION.

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. ENERGY

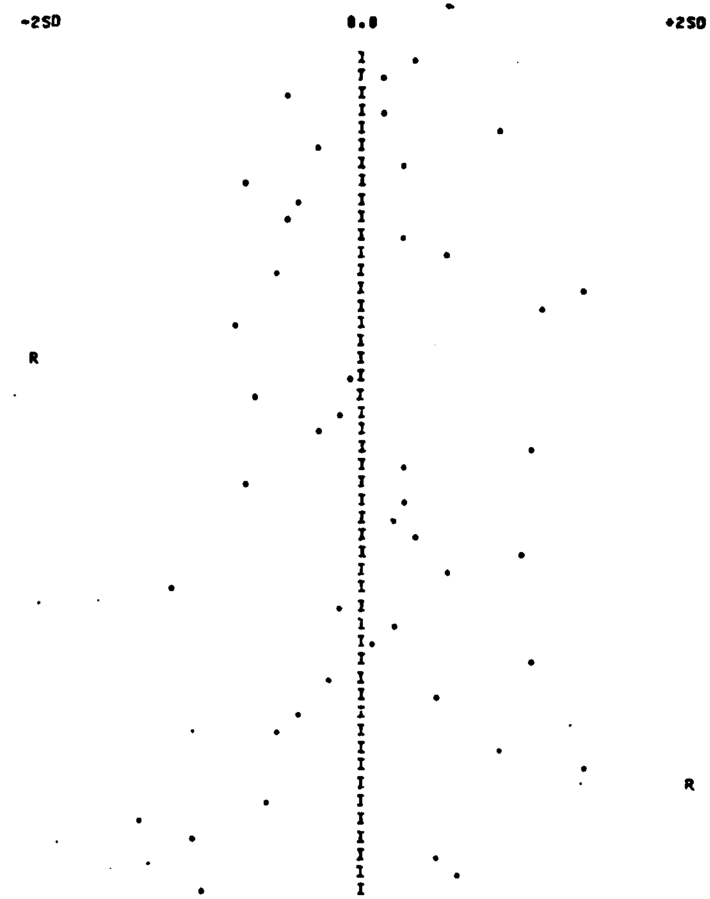
S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	HEATDAYS		289.24662	0	.92681	.85899	.85899	.92561	280.24662	.0.6
2	COOLDAYS		10.83088	.002	.94142	.88628	.02729	-.02112	175.35169	.0.0
3	CAPINV		1.61549	.319	.94279	.88884	.00257	-.13367	117.27987	0
4	MANMTHS		3.23444	.079	.94490	.89662	.00778	.20330	93.23536	.000

ALC ENERGY REGRESSION RESEARCH QUESTION TWO. 05/19/80 08.43.33. PAGE 9
STEPWISE, INCLUSION LEVEL UNSPECIFIED
FILE NONAME (CREATION DATE = 05/19/80)

* M U L T I P L E R E G R E S S I O N *

OBSERVATION	Y VALUE	Y ESTIMATE	RESIDUAL
1.	1269154.	1241724.	27430.41
2.	1504317.	1496341.	7976.721
3.	1691149.	1729323.	-38174.67
4.	*1810669.	1802795.	7684.155
5.	1608909.	1537671.	71138.19
6.	1461697.	1478373.	-16676.33
7.	1294037.	1276155.	17882.06
8.	1069427.	1129368.	-59941.06
9.	1116389.	1148588.	-32199.12
10.	1164734.	1203051.	-38316.51
11.	1205211.	1183256.	21954.94
12.	1166858.	1123439.	43378.51
13.	1205175.	1247093.	-41917.55
14.	1568010.	1456025.	111985.3
15.	*1776877.	1686726.	90150.60
16.	1782676.	1848575.	-65899.22
17.	*1531888.	1498720.	33168.15
18.	1427151.	1781217.	-354065.9
19.	1169989.	1174218.	-4228.923
20.	1161711.	1215272.	-53563.02
21.	1186039.	1196237.	-10227.91
22.	1207435.	1225544.	-18107.93
23.	1265785.	1202275.	63511.35
24.	1210281.	1193641.	16640.27
25.	1126717.	1152851.	-56143.98
26.	1409995.	1388029.	21967.00
27.	1642904.	1630070.	12833.65
28.	1841499.	1815911.	25577.56
29.	1766237.	1683524.	62712.90
30.	1496746.	1453875.	42870.67
31.	1188527.	1282512.	-93984.89
32.	1218950.	1220045.	-6095.728
33.	1235513.	1222864.	12658.96
34.	1259181.	1255872.	3309.411
35.	1328493.	1245166.	83331.51
36.	*1223494.	1239460.	-15965.90
37.	1243997.	1206045.	37952.21
38.	1441797.	1472914.	-31120.76
39.	1717846.	1759036.	-41190.07
40.	1997256.	1928233.	69063.47
41.	1788091.	1677436.	111219.3
42.	1499912.	1318413.	181499.8
43.	1246096.	1291757.	-45661.73
44.	1095771.	1208004.	-112234.3
45.	1121093.	1205831.	-84131.76
46.	1241023.	1204572.	36448.49
47.	1265405.	1213873.	46527.02
48.	*1144218.	1223226.	-79007.59



NOTE - (*) INDICATES ESTIMATE CALCULATED WITH MEANS SUBSTITUTED
R INDICATES POINT OUT OF RANGE OF PLOT

```
VON NEUMANN RATIO     1.93265           DURBIN-WATSON TEST     1.89235

NUMBER OF POSITIVE RESIDUALS      26.
NUMBER OF NEGATIVE RESIDUALS      22.
NUMBER OF RUNS OF SIGNS           24.

EXPECTED NUMBER OF RUNS OF SIGNS               25.
EXPECTED S.D. OF RUN DISTRIBUTION         3.40273
UNIT NORMAL DEVIATE-
  Z=(EXPECTED-OBSERVED)/S.D.              -.09796
PROBABILITY OF OBTAINING .GE. ABS(Z)       .46098


RESIDUALS -         48 CASES WRITTEN ON FILE BCDOUT
```

```
ALC ENERGY REGRESSION RESEARCH QUESTION TWO.
ENERGY WITH SQFT REGRESSION                                          05/10/80     15.27.36.     PAGE  17
FILE    NONAME    (CREATION DATE =  05/10/80 )

* * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * * * * * * * * * * *

DEPENDENT VARIABLE..     ENERGY

MEAN RESPONSE  1383476.47917       STD. DEV.  246550.66174

VARIABLE(S) ENTERED ON STEP NUMBER   1..    SQFT

MULTIPLE R              .18854        ANALYSIS OF VARIANCE    DF       SUM OF SQUARES           MEAN SQUARE              F      SIGNIFICANCE
R SQUARE                .03259        REGRESSION               1.   93121454494.17187   93121454494.17187        1.54985           .219
ADJUSTED R SQUARE       .01156        RESIDUAL                45.2763878299262.29687   60864310853.52808
STD DEVIATION  245121.81267           COEFF OF VARIABILITY    17.7 PCT

-------------------- VARIABLES IN THE EQUATION ---------------------       ---------- VARIABLES NOT IN THE EQUATION -----------
VARIABLE          B             STD ERROR B         F            BETA          VARIABLE      PARTIAL     TOLERANCE        F
                                               ------------  ----------                                              ------------
                                               SIGNIFICANCE  ELASTICITY                                              SIGNIFICANCE
SQFT         -.32134111E-01   .25812018E-01    1.5498464     -.1805385
                                                    .219
(CONSTANT)    3318724.0        1578967.3       4.5167575     -1.41328
                                                    .039

ALL VARIABLES ARE IN THE EQUATION.


DEPENDENT VARIABLE..     ENERGY

                                                  S U M M A R Y   T A B L E
STEP       VARIABLE                    F TO       SIGNIFICANCE  MULTIPLE R  R SQUARE  R SQUARE  SIMPLE R        OVERALL F   SIGNIFICANCE
      ENTERED    REMOVED          ENTER OR REMOVE                                      CHANGE
  1   SQFT                            1.54985        .219          .18854     .03259    .03259   -.18854         1.54985        .219
```

```
ALC ENERGY REGRESSION RESEARCH QUESTION TWO.                              05/10/80     13.27.36.     PAGE   23
ENERGY WITH CAPINV REGRESSION
FILE   NONAME   (CREATION DATE =  05/13/80 )

* * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * * * * * * * * * * * *

DEPENDENT VARIABLE..    ENERGY

MEAN RESPONSE  1383478.47917       STD. DEV.  246550.66174

VARIABLE(S) ENTERED ON STEP NUMBER   1..    CAPINV

MULTIPLE R              .13387        ANALYSIS OF VARIANCE     DF       SUM OF SQUARES        MEAN SQUARE             F      SIGNIFICANCE
R SQUARE                .01792        REGRESSION                1.  51198183180.56250  51198183180.56250        .03937           .364
ADJUSTED R SQUARE            0        RESIDUAL                 46.2865601570575.90625  68995686316.86743
STD DEVIATION  246973.04775           COEFF OF VARIABILITY     17.9 PCT

-------------------- VARIABLES IN THE EQUATION ---------------------          ---------- VARIABLES NOT IN THE EQUATION -----------

VARIABLE           B          STD ERROR B          F           BETA            VARIABLE      PARTIAL     TOLERANCE          F
                                              ------------  -----------                                               ------------
                                              SIGNIFICANCE  ELASTICITY                                                SIGNIFICANCE

CAPINV       -.01132702        .06726121        .03937384    -.1339666
                                                     .364      -.43519
(CONSTANT)   1985550.0         658125.07        9.1021519
                                                     .004

ALL VARIABLES ARE IN THE EQUATION.


DEPENDENT VARIABLE..    ENERGY

                                          S U M M A R Y   T A B L E

STEP      VARIABLE               F TO        SIGNIFICANCE  MULTIPLE R  R SQUARE  R SQUARE  SIMPLE R       OVERALL F   SIGNIFICANCE
     ENTERED   REMOVED      ENTER OR REMOVE                                       CHANGE

  1  CAPINV                      .03937         .364          .13387     .01792    .01792   -.13387         .03937        .364
```

```
ALC ENERGY REGRESSION RESEARCH QUESTION TWO.                                  05/06/80     23.17.26.     PAGE  10
ENERGY WITH MANMONTHS REGRESSION
FILE   NONAME   (CREATION DATE =  05/05/80 )

* * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * * * * * * * * * *

DEPENDENT VARIABLE..     ENERGY

MEAN RESPONSE  1383475.47917       STD. DEV.  246558.66174

VARIABLE(S) ENTERED ON STEP NUMBER   1..   MANMTHS

MULTIPLE R              .20330        ANALYSIS OF VARIANCE    DF       SUM OF SQUARES        MEAN SQUARE           F      SIGNIFICANCE
R SQUARE                .04133        REGRESSION               1.  118.0351107 0.39062 118.0351107 0.39062      1.98321          .166
ADJUSTED R SQUARE       .02049        RESIDUAL                46.27393162 2686.07812  595.1657 49.69727
STD DEVIATION  244011.59286           COEFF OF VARIABILITY    17.6 PCT

-------------------- VARIABLES IN THE EQUATION ---------------------          ---------- VARIABLES NOT IN THE EQUATION -----------

VARIABLE            B           STD ERROR B          F           BETA           VARIABLE       PARTIAL     TOLERANCE        F
                                                ------------  -----------                                              ------------
                                                SIGNIFICANCE  ELASTICITY                                               SIGNIFICANCE

MANMTHS        26.688697        19.087963       1.9832083     .2033.10
                                                     .166     1.38266
(CONSTANT)   -529321.33        1358724.2        .15176662
                                                     .699

ALL VARIABLES ARE IN THE EQUATION.



DEPENDENT VARIABLE..     ENERGY

                                              S U M M A R Y   T A B L E

STEP       VARIABLE                   F TO       SIGNIFICANCE  MULTIPLE R   R SQUARE  R SQUARE  SIMPLE R       OVERALL F   SIGNIFICANCE
      ENTERED   REMOVED          ENTER OR REMOVE                                        CHANGE

  1   MANMTHS                       1.98321          .166         .20330      .04133    .04133   .2 330          1.98321        .166
```

APPENDIX K

NORMALIZED REGRESSION--ENERGY CONSUMPTION NORMALIZED BY HEATING DEGREE DAYS (NORMENGH) AND COOLING DEGREE DAYS (NORMENGC)

ALC ENERGY REGRESSION RESEARCH QUESTION TWO.
ENERGY NORMALIZED BY HEATING AND COOLING DEGREE DAYS
FILE NONAME (CREATION DATE = 05/10/80)

VARIABLE	MEAN	STANDARD DEV	CASES
NORMENGH	51459.0997	202965.5616	48
MANMTHS	71158.3360	1864.6699	48
SQFT	60345416.5417	1385190.9662	48
CAPINV	384861.2917	53988.9342	48

CORRELATION COEFFICIENTS.

A VALUE OF 99.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.

MANMTHS	-.21108		
SQFT	.21092	-.90517	
CAPINV	.20163	-.86186	.95245
	NORMENGH	MANMTHS	SQFT

* MULTIPLE REGRESSION *

DEPENDENT VARIABLE.. NURMENGH

MEAN RESPONSE 51433. 9569 STD. DEV. 202965.56157

VARIABLE(S) ENTERED ON STEP NUMBER 1.. MANMTHS

MULTIPLE R	.21168	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.04456	REGRESSION	1.	86265393935.75000	86265393935.75000	2.14511	.150
ADJUSTED R SQUARE	.02378	RESIDUAL	46.	1849900007063.31250	40215217557.89795		
STD DEVIATION	200537.32211	COEFF OF VARIABILITY	339.7 PCT				

---------------------- VARIABLES IN THE EQUATION ----------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
MANMTHS	-22.975635	15.687160	2.1451057 / .150	-.2116606 / -31.77110
(CONSTANT)	1686371.4	1110047.4	2.2807324 / .138	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
SQFT	.04779	.18066	.10300152 / .750
CAPINV	.03975	.25719	.71225078E-01 / .791

* *

VARIABLE(S) ENTERED ON STEP NUMBER 2.. SQFT

MULTIPLE R	.21619	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.04674	REGRESSION	2.	90490502372.39844	45245251186.19922	1.10314	.341
ADJUSTED R SQUARE	.00437	RESIDUAL	45.	1845675399226.66406	41015008871.70361		
STD DEVIATION	202521.62589	COEFF OF VARIABILITY	393.6 PCT				

---------------------- VARIABLES IN THE EQUATION ----------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
MANMTHS	-12.147983	37.272396	.10622852 / .746	-.1115151 / -16.73841
SQFT	.14162673E-01	.50173702E-01	.10300152 / .750	.1059869 / 19.14417
(CONSTANT)	-53980.123	568976.3	.13165963E-13 / .991	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
CAPINV	.01259	.09285	.29435768E-03 / .986

F-LEVEL OR TOLERANCE-LEVEL INSUFFICIENT FOR FURTHER COMPUTATION.

ALC ENERGY REGRESSION RESEARCH QUESTION TWO.   05/07/83   23.26.50.   PAGE 19
ENERGY NORMALIZED BY HEATING AND COOLING DEGREE DAYS
FILE NONAME (CREATION DATE = 05/07/80)

* M U L T I P L E   R E G R E S S I O N *

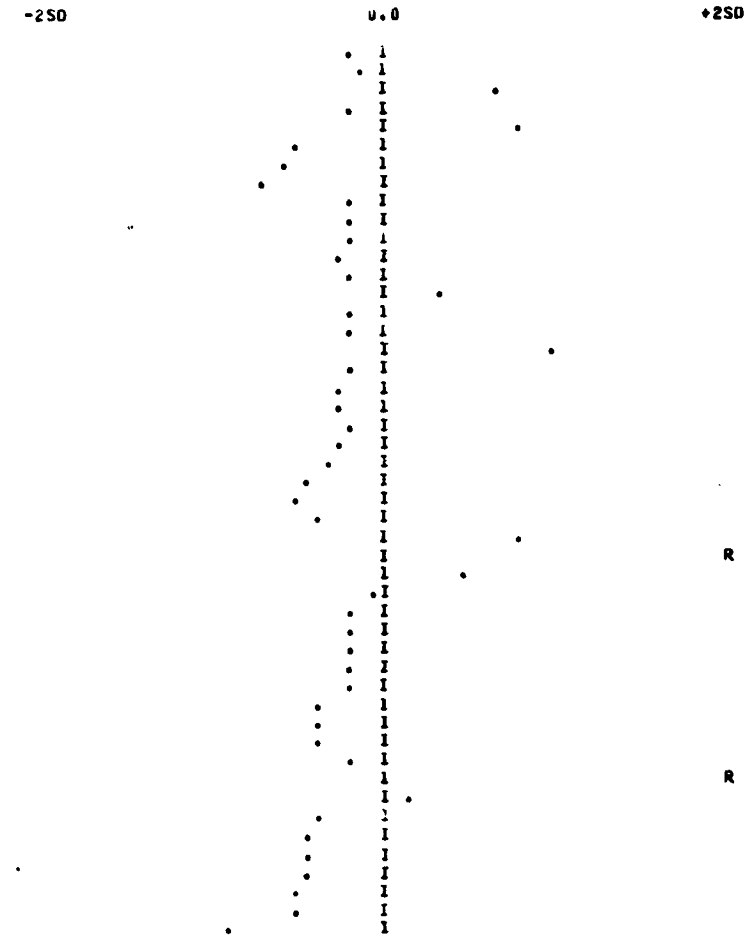
DEPENDENT VARIABLE.. NORMENGH

SUMMARY TABLE

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	MANMTHS		2.14511	.150	.21116	.04459	.04456	-.21118	2.14511	.150
2	SOFT		.10300	.750	.21519	.04674	.00218	.21092	1.10314	.341

MULTIPLE REGRESSION

OBSERVATION	Y VALUE	Y ESTIMATE	RESIDUAL
1.	2845.337	47850.17	-45004.83
2.	19041.59	52730.22	-33688.24
3.	338223.6	121293.1	216936.5
4.	9041.12	134743.5	-65165.39
5.	402202.3	154027.9	248174.4
6.	15717.17	174845.4	-159128.3
7.	5369.448	197655.3	-192287.3
8.	1627.743	241461.3	-239833.6
9.	797.4237	65427.65	-64630.24
10.	537.7350	50237.21	-49699.47
11.	601.1027	60079.46	-60078.38
12.	944.0680	72982.63	-72038.56
13.	5285.855	49435.01	-44149.16
14.	156801.0	60840.02	95960.98
15.	0	63495.73	-63495.73
16.	0	65738.63	-65738.53
17.	382972.0	65811.83	317169.2
18.	18065.20	70921.75	-52856.54
19.	4285.674	83669.52	-79383.81
20.	1362.989	78463.81	-77080.81
21.	619.0026	66720.80	-66101.88
22.	509.2518	77003.09	-76493.84
23.	594.4457	90928.31	-90333.86
24.	774.3321	146894.7	-146121.3
25.	3383.505	162089.1	-158705.6
26.	29374.9	156077.7	-126702.8
27.	410726.0	155093.0	255627.0
28.	920744.5	165534.0	755211.5
29.	234372.8	155022.5	139350.4
30.	36506.00	51359.40	-14853.40
31.	3634.339	55400.27	-51765.53
32.	1254.943	57577.56	-56322.63
33.	738.5015	49926.20	-49187.70
34.	506.4332	49804.24	-49297.81
35.	636.5387	55453.22	-54826.56
36.	865.2716	117684.7	-117019.4
37.	3165.387	131175.4	-128010.0
38.	12115.60	129834.0	-117718.1
39.	81862.19	135898.1	-54095.93
40.	1997250.	147963.4	1849288.
41.	178868.1	154545.7	24321.42
42.	17736.93	138927.6	-121191.7
43.	255.257	143351.5	-143096.2
44.	1423.357	150221.6	-148804.8
45.	776.7399	146155.3	-145378.5
46.	678.133	164099.5	-163416.4
47.	610.0540	170834.8	-170222.7
48.	866.8160	294034.3	-293165.5



NOTE - (*) INDICATES ESTIMATE CALCULATED WITH MEANS SUBSTITUTED
R INDICATES POINT OUT OF RANGE OF PLOT

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VON NEUMANN RATIO    1.77424          DURBIN-WATSON TEST    1.73727

NUMBER OF POSITIVE RESIDUALS      9.
NUMBER OF NEGATIVE RESIDUALS     39.
NUMBER OF RUNS OF SIGNS          13.

NORMAL APPROXIMATION TO SIGN DISTRIBUTION IMPOSSIBLE.
USE A TABLE FOR EXPECTED VALUES.


RESIDUALS -         48  CASES WRITTEN ON FILE BCDOUT
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ALC ENERGY REGRESSION RESEARCH QUESTION TWO.
ENERGY NORMALIZED BY HEATING AND COOLING DEGREE DAYS
FILE   NONAME    (CREATION DATE =  05/10/80 )

VARIABLE              MEAN        STANDARD DEV      CASES

NORMENGC      113171.0941        325252.5589         48
MANMTHS        71158.3360          1864.6699         48
SQFT        60846416.5417       1385190.9662         48
CAPINV        984861.2917         53988.9342         48


CORRELATION COEFFICIENTS.

A VALUE OF 99.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.

MANMTHS        -.03724
SQFT            .00338    -.90517
CAPINV          .05000    -.86186     .95245

              NORMENGC    MANMTHS     SQFT
```

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ALC ENERGY REGRESSION RESEARCH QUESTION TWO.                                  05/07/81     23.26.5 .     PAGE  11
ENERGY NORMALIZED BY HEATING AND COOLING DEGREE DAYS
FILE   NONAME    (CREATION DATE =  05/07/80 )

* * * * * * * * * * * *   * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * *   * * * * * * * * * * * * * * *   * * *

DEPENDENT VARIABLE..     NORMENGC

MEAN RESPONSE   113171.09414       STD. DEV.   325252.55667

VARIABLE(S) ENTERED ON STEP NUMBER   1..    CAPINV

MULTIPLE R               .05601        ANALYSIS OF VARIANCE    DF       SUM OF SQUARES          MEAN SQUARE                 F      SIGNIFICANCE
R SQUARE                 .00250        REGRESSION               1.  12131400579.31250  12431400573.31250             .11530            .736
ADJUSTED R SQUARE         0            RESIDUAL                 .6.4959162265960.71875 107818744934.17254
STD DEVIATION  326357.64796            COEFF OF VARIABILITY   231.1 PCT

-------------------- VARIABLES IN THE EQUATION ---------------------          ---------- VARIABLES NOT IN THE EQUATION -----------

VARIABLE           B          STD ERROR B         F            BETA           VARIABLE      PARTIAL    TOLERANCE        F
                                             ------------  ----------                                              ------------
                                             SIGNIFICANCE  ELASTICITY                                              SIGNIFICANCE

CAPINV      .3 123560       .98714204       .11529910      .05516.24      MANMTHS        .01155       .25719     .6004.2158E-02
                                                 .736       2.62146                                                      .939
(CONSTANT)  -183504.27      674396.95       .43982436E-01                 SOFT          -.14537       .09285     .97153339
                                                 .835                                                                    .330

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

VARIABLE(S) ENTERED ON STEP NUMBER   2..    SOFT

MULTIPLE R               .15356        ANALYSIS OF VARIANCE    DF       SUM OF SQUARES          MEAN SQUARE                 F      SIGNIFICANCE
R SQUARE                 .02358        REGRESSION               2.  1172457.3632.31250  58622385316.15625             .54338            .585
ADJUSTED R SQUARE         0            RESIDUAL                 .5.485.647692515.71875 107885530731.45996
STD DEVIATION  328459.25540            COEFF OF VARIABILITY   210.2 PCT

-------------------- VARIABLES IN THE EQUATION ---------------------          ---------- VARIABLES NOT IN THE EQUATION -----------

VARIABLE           B          STD ERROR B         F            BETA           VARIABLE      PARTIAL    TOLERANCE        F
                                             ------------  ----------                                              ------------
                                             SIGNIFICANCE  ELASTICITY                                              SIGNIFICANCE

CAPINV      3.13133.2       2.9123591       1.0662335      .5538376       MANMTHS       -.00170       .18066     .29566681
                                                 .303       20.41.72                                                     .589
SOFT        -.11166424      .11351154       .97153339      -.4714544
                                                 .330       -05.15454
(CONSTANT)  3071542.7       .265061.9       .84947992
                                                 .362
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ALC ENERGY REGRESSION - RESEARCH QUESTION TWO.                                  05/07/81)    23.26...     PAGE  12
ENERGY NORMALIZED BY HEATING AND COOLING DEGREE DAYS
FILE    NONAME    (CREATION DATE =  05/07/80 )

* * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E    R E G R E S S I O N  * * * * * *  * * * * * * * * * * * * * * *

DEPENDENT VARIABLE..     NORMENGC

VARIABLE(S) ENTERED ON STEP NUMBER   3..    MANMTHS

MULTIPLE R             .17349        ANALYSIS OF VARIANCE     DF      SUM OF SQUARES         MEAN SQUARE              F       SIGNIFICANCE
R SQUARE               .03010        REGRESSION               3.  1130511-0336.15025  49863:15445.36525        .45514         .715
ADJUSTED R SQUARE           0        RESIDUAL                44.4822442525211.67500  1396009366482.06789
STD DEVIATION  331660.36682          COEFF OF VARIABILITY    232.5 PCT

-------------------- VARIABLES IN THE EQUATION ---------------------          ---------- VARIABLES NOT IN THE EQUATION -----------

VARIABLE            B          STD ERROR B          F            BETA         VARIABLE       PARTIAL     TOLERANCE         F
                                                ------------  -----------                                            ------------
                                                SIGNIFICANCE  ELASTICITY                                             SIGNIFICANCE

CAPINV       3. 365651        2.9394261        1.0715050      .5043739
                                                     .306     26.44284
SOFT        -.16237283         .13650746       1.2459568     -.0465282
                                                     .270     -81.92325
MANMTHS     -33.136026       63.928565         .29566661     -.1893341
                                                     .589     -20.63109
(CONSTANT)   979427.9        984479.6          .78926152
                                                     .379

ALL VARIABLES ARE IN THE EQUATION.

* * * * * * * * * * * - * * * * * * * * * * *  M U L T I P L E    R E G R E S S I O N  * * * * * * * * * * * * * * * * * * * * * * *

DEPENDENT VARIABLE..     NORMENGC

                                              S U M M A R Y   T A B L E

STEP        VARIABLE                  F TO        SIGNIFICANCE  MULTIPLE R  R SQUARE  R SQUARE  SIMPLE R        OVERALL F   SIGNIFICANCE
       ENTERED    REMOVED       ENTER OR REMOVE                                       CHANGE

  1    CAPINV                        .11130          .736         .05001     .00250    .00250    .05000          .11130         .736
  2    SOFT                          .97133          .330         .15346     .02356    .02106    .13336          .54338         .585
  3    MANMTHS                       .29567          .589         .17349     .03010    .00652   -.03724          .45514         .716
```

ALC ENERGY REGRESSION RESEARCH QUESTION TWO. 05/07/83 23.26.50. PAGE 20
ENERGY NORMALIZED BY HEATING AND COOLING DEGREE DAYS
FILE NONAME (CREATION DATE = 05/07/80)

* M U L T I P L E R E G R E S S I O N *

OBSERVATION	Y VALUE	Y ESTIMATE	RESIDUAL	-2SD 0.0 +2SD
1.	1917.151	-50483.18	52400.33	
2.	760.9159	-48693.73	49400.59	
3.	515.9355	-45700.08	46216.78	
4.	90.6952	-40767.82	41258.52	
5.	663.7001	-33697.61	34361.51	
6.	676.7116	-26064.53	26741.21	
7.	1122.322	-17700.13	18822.45	
8.	2756.255	-1638.353	4394.309	
9.	10531.97	49075.86	-38543.89	
10.	0	43505.88	-43505.86	
11.	200853.1	47334.81	153533.7	
12.	15353.43	51846.08	-36492.56	
13.	1172.349	40394.16	-39221.81	
14.	705.6751	44576.11	-43870.43	
15.	521.6903	45549.89	-45028.20	
16.	420.9388	46372.31	-45951.37	
17.	622.9719	46399.16	-45776.19	
18.	377.8531	48268.21	-47890.36	
19.	1770.329	52942.52	-51172.49	
20.	1910.709	51033.70	-49122.99	
21.	131773.8	46727.85	85056.33	
22.	0	50498.10	-50498.10	
23.	61227.90	55604.14	5623.764	
24.	10433.46	49880.85	-39447.41	
25.	1754.395	55452.30	-53697.30	
26.	790.7992	53248.04	-52457.24	
27.	542.9293	52889.19	-52346.26	
28.	459.5050	56715.44	-56255.88	
29.	535.8729	52861.13	-52325.25	
30.	769.5352	73051.02	-72281.49	
31.	1227.317	74532.71	-73304.39	
32.	2922.152	75331.08	-72408.89	
33.	17650.19	72525.50	-54875.31	
34.	629590.5	72502.78	557087.7	R
35.	51096.08	74555.79	-23459.72	
36.	6210.629	78441.17	-72230.55	
37.	2429.552	83314.58	-80884.30	
38.	728.9115	82822.71	-82093.80	
39.	491.7357	85046.28	-84554.40	
40.	53.6125	89472.16	-89018.54	
41.	567.655	91884.26	-91316.61	
42.	1259.427	98875.22	-97615.80	
43.	1189.554	100497.3	-99307.76	
44.	2575.778	103011.0	-100435.2	
45.	10483.17	101525.4	-91042.26	
46.	0	108163.3	-108163.3	
47.	1265405.	110575.3	1154829.	R
48.	24345.5	117531.5	-93185.44	

NOTE - (*) INDICATES ESTIMATE CALCULATED WITH MEANS SUBSTITUTED
R INDICATES POINT OUT OF RANGE OF PLOT

```
VON NEUMANN RATIO     1.81592          DURBIN-WATSON TEST     1.77809

NUMBER OF POSITIVE RESIDUALS       9.
NUMBER OF NEGATIVE RESIDUALS      39.
NUMBER OF RUNS OF SIGNS           13.

NORMAL APPROXIMATION TO SIGN DISTRIBUTION IMPOSSIBLE.
USE A TABLE FOR EXPECTED VALUES.


RESIDUALS -         48  CASES WRITTEN ON FILE BCDOUT
```

APPENDIX L

LOG-LINEAR REGRESSION

ALC ENERGY REGRESSION RESEARCH QUESTION TWO. 05/06/80 23.17.26. PAGE 18
LOG LINEAR ENERGY REGRESSION
FILE NONAME (CREATION DATE = 05/06/80)

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LNENERGY

MEAN RESPONSE 14.12549 STD. DEV. .17827

VARIABLE(S) ENTERED ON STEP NUMBER 1.. LNMMS
LNCOOL
LNHEAT
LNCAPINV
LNSOFT

MULTIPLE R	.93365	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.87170	REGRESSION	5.	1.18776	.23755	57.07249	0
ADJUSTED R SQUARE	.85643	RESIDUAL	42.	.17482	.00416		
STD DEVIATION	.06452	COEFF OF VARIABILITY	.5 PCT				

-------------------- VARIABLES IN THE EQUATION --------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LNMMS	3.0476558	.89502649	11.594725	.4616307
			.001	2.41150
LNCOOL	-.77340623E-01	.60786165E-02	161.88474	-1.1379213
			0	-.02752
LNHEAT	-.19825323E-01	.60606328E-02	10.700513	-.3017056
			.002	-.00816
LNCAPINV	.95995832	.60478479	2.5194343	.3085650
			.120	.93776
LNSOFT	1.0404219	1.6599251	.39286391	.1402439
			.534	1.32017
(CONSTANT)	-51.314256	30.877994	2.7617089	
			.104	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LNENERGY

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	LNMMS		11.53472	.001	.21379	.04787	.04787	.21879	57.07209	0
	LNCOOL		161.88474	0	.90686	.81154	.76367	-.90051		
	LNHEAT		10.73051	.002	.91313	.83380	.02226	.61026		
	LNCAPINV		2.51943	.120	.933 1	.87050	.03670	-.1.135		
	LNSQFT		.33286	.534	.93365	.87170	.00120	-.18867		

ALC ENERGY REGRESSION RESEARCH QUESTION TWO. 05/07/80 23.26.50. PAGE 30
LOG LINEAR ENERGY REGRESSION
FILE NONAME (CREATION DATE = 05/07/80)

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LNENERGY

PARAMETERS.. MAXIMUM STEP 8 F TO ENTER 7.030
TOLERANCE .0010 F TO REMOVE 4.080

MEAN RESPONSE 14.12549 STD. DEV. .17027

VARIABLE(S) ENTERED ON STEP NUMBER 1.. LNCOOL

MULTIPLE R	.90051	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.81092	REGRESSION	1.	1.10494	1.10494	197.28231	0
ADJUSTED R SQUARE	.80681	RESIDUAL	46.	.25764	.00560		
STD DEVIATION	.07484	COEFF OF VARIABILITY	.5 PCT				

-------------------- VARIABLES IN THE EQUATION --------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LNCOOL	-.61204630E-01	.43575282E-02	197.28231 / 0	-.9005106 / -.02178
(CONSTANT)	14.433134	.24421924E-01	349270.22 / 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LNHMS	.05745	.95340	.14901692 / .701
LNSQFT	.10274	.93464	.48044013 / .492
LNCAPINV	.12769	.95265	.74563979 / .392

F-LEVEL OR TOLERANCE-LEVEL INSUFFICIENT FOR FURTHER COMPUTATION.

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	LNCOOL		197.28231	0	.90051	.81092	.81092	-.90051	197.28231	0

ALC ENERGY REGRESSION RESEARCH QUESTION TWO. 05/03/80 11.39.28. PAGE 36
NATURAL LOG OF ENERGY REGRESSED WITH RECIPORICAL OF COOLDAYSLN
FILE NONAME (CREATION DATE = 05/03/80)

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. LNENERGY

MEAN RESPONSE 5.47276 STD. DEV. .39528

VARIABLE(S) ENTERED ON STEP NUMBER 1.. LNCOOLD

MULTIPLE R	.95327	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.90873	REGRESSION	1.	6.67338	6.67338	457.98177	0
ADJUSTED R SQUARE	.90674	RESIDUAL	46.	.67028	.01457		
STD DEVIATION	.12071	COEFF OF VARIABILITY	1.9 PCT				

--------------------- VARIABLES IN THE EQUATION ---------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LNCOOLD	.15041371	.70285116E-02	457.98177 0	.95327?17 -.11681
(CONSTANT)	7.2288099	.39391543E-01	33676.552 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

ALC ENERGY REGRESSION RESEARCH QUESTION TWO. 05/03/80 11.39.28. PAGE 37
NATURAL LOG OF ENERGY REGRESSED WITH RECIPORICAL OF COOLDAYSLN
FILE NONAME (CREATION DATE = 05/03/80)

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. LNENERGY

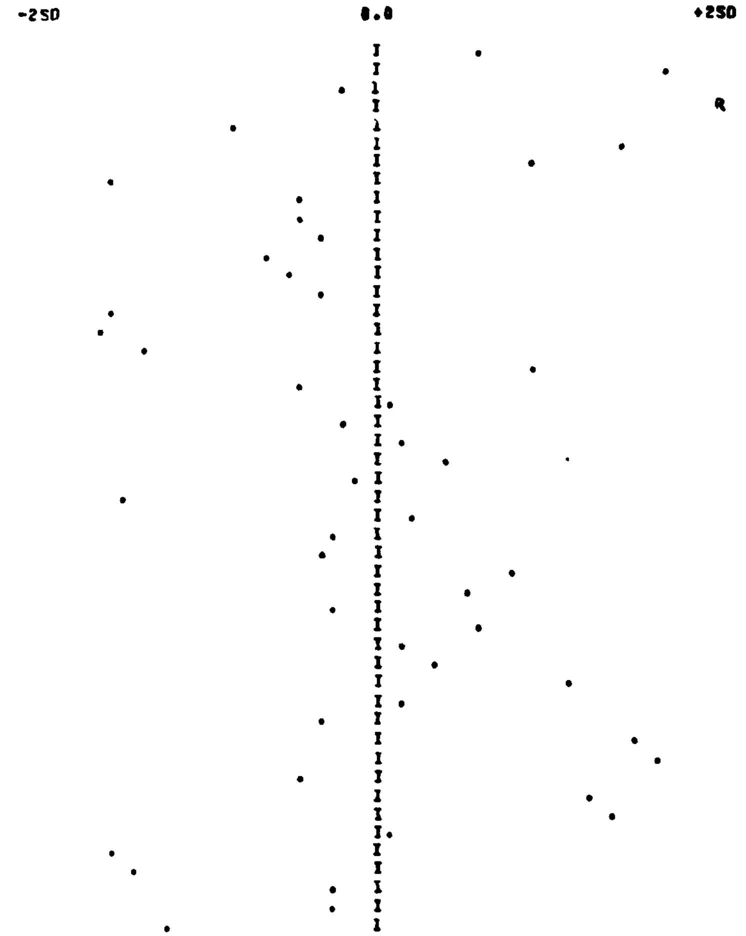
S U M M A R Y T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	LNCOOLD		457.98177	0	.95327	.90873	.90873	.95327	457.98177	0

ALC ENERGY REGRESSION RESEARCH QUESTION TWO. 05/03/83 11.39.28. PAGE 38
NATURAL LOG OR ENERGY REGRESSED WITH RECIPORICAL OF COOLDAYSLN
FILE NONAME (CREATION DATE = 05/03/80)

• M U L T I P L E R E G R E S S I O N •

OBSERVATION	Y VALUE	Y ESTIMATE	RESIDUAL
1.	6.378506	6.311238	.6726771E-01
2.	6.777725	6.571385	.2061402
3.	6.966637	6.986728	-.2009114E-01
4.	7.073199	6.738747	.3344510
5.	6.916050	7.020292	-.1042424
6.	6.717715	6.547345	.1706704
7.	6.515351	6.403821	.1115298
8.	6.064032	6.252973	-.1888811
9.	6.083234	6.139179	-.5594436E-01
10.	6.022650	6.073537	-.5088119E-01
11.	6.049913	6.085154	-.3524168E-01
12.	6.080551	6.157319	-.7736821E-01
13.	6.353218	6.412162	-.5894378E-01
14.	6.848957	6.882478	-.3351215E-01
15.	7.041964	7.228310	-.1866454
16.	7.030561	7.226310	-.1963988
17.	6.856731	7.020292	-.1635608
18.	6.681415	6.571385	.1098304
19.	6.335313	6.385368	-.4975532E-01
20.	6.217881	6.216014	.1866827E-02
21.	6.071878	6.091984	-.2010585E-01
22.	6.073404	6.059935	.1346908E-01
23.	6.116845	6.073745	.4310814E-01
24.	6.112414	6.122513	-.1019927E-01
25.	6.177712	6.355186	-.1774730
26.	6.670153	6.646528	.2362453E-01
27.	6.992326	7.020292	-.2796601E-01
28.	7.085925	7.124551	-.3862614E-01
29.	7.048977	6.959305	.8967234E-01
30.	6.732230	6.670238	.6199206E-01
31.	6.330603	6.357320	-.2731761E-01
32.	6.202737	6.134215	.6852152E-01
33.	6.122399	6.112383	.1001540E-01
34.	6.104474	6.069630	.3484436E-01
35.	6.212023	6.079125	.1328975
36.	6.151148	6.137582	.1336623E-01
37.	6.290798	6.330267	-.3946953E-01
38.	6.687385	6.509364	.1774209
39.	6.970205	6.771372	.1993331
40.	7.174366	7.228810	-.5474428E-01
41.	7.035238	6.882470	.1527683
42.	6.724419	6.562354	.1620549
43.	6.413901	6.406339	.7562825E-02
44.	6.040317	6.229102	-.1887850
45.	5.959225	6.134524	-.1752988
46.	6.667877	6.698391	-.3101454E-01
47.	6.055413	6.081523	-.2610957E-01
48.	5.996654	6.148371	-.1517178



NOTE - (*) INDICATES ESTIMATE CALCULATED WITH MEANS SUBSTITUTED
R INDICATES POINT OUT OF RANGE OF PLOT

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